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Feasibility
of
Establishing
a


Fullers
Earth
Processing
Plant

in
Marshall County,
Kentucky

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Feasibility of Establishing

a

Fullers Earth

Processing Plant

in

Marshall County, Kentucky

by

Spindletop Research Center
Lexington, Kentucky

prepared for

U.S. DEPARTMENT OF COMMERCE

John T. Connor, Secretary

Area Redevelopment Administration
William L. Batt, Jr., Administrator

February 1965

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FOREWORD

The basic responsibility of the Area Redevelopment Administration of the U.S. Department of Commerce is to help revitalize the economies of American communities suffering from chronic unemployment and underemployment.

One way of assisting a community is to determine the kinds and the magnitudes of its economic problems and the possible solutions. ARA helps do this through its Technical Assistance program.

This publication is a product of a technical assistance contract with the Spindletop Research Center, Lexington, Kentucky.

The study surveys the mineral resources of Marshall County, Kentucky, and suggests that its deposits of fuller's earth are sufficient to justify a plant to process the material. The conclusions and recommendations have general, broader applicability to any area which has deposits of this mineral.

William L. Batt, Jr., Administrator
Area Redevelopment Administration

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Section 1

INTRODUCTION

Marshall County is located in the Jackson Purchase Area of Western Kentucky, approximately 10 miles south of Paducah. (See Figure 1-1.) Here, as well as in extreme southern Illinois, eastern Missouri, western Tennessee, northern Mississippi and northeastern Arkansas, there are extensive deposits of several commercially important clays. One of the most widespread of these clay deposits is composed almost entirely of the mineral montmorillonite. Called the Porter's Creek Clay in Kentucky, it is well known for its natural bleaching and absorbing properties. Fuller's earth is the common name for this clay.

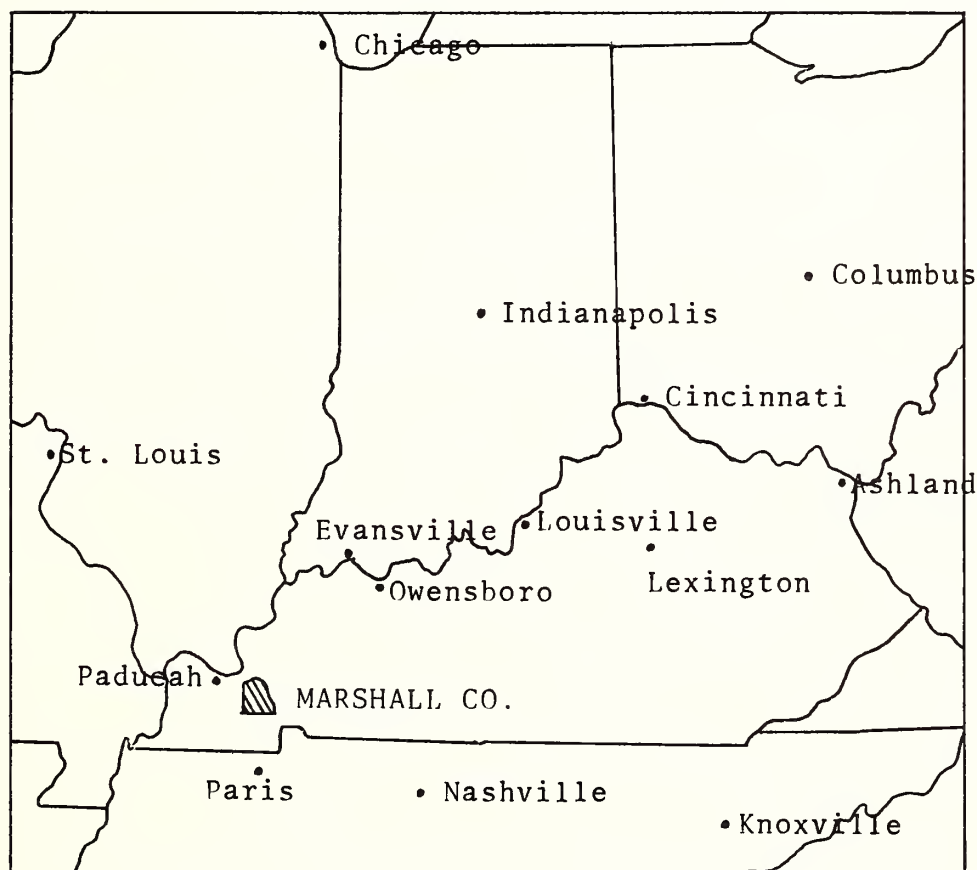


Figure 1-1

STUDY AREA LOCATION REFERENCE MAP

D. J. Enterprise of Benton, Kentucky, leased mineral rights on two farms underlain by Porter's Creek Clay in Marshall County, Kentucky (Figure 1-2); an application for a technical assistance grant was approved by the Area Redevelopment Administration to determine the feasibility of establishing a clay processing plant for fuller's earth products utilizing the clay from these properties. Spindletop Research, Inc., was awarded a contract (No. Cc-6030) by the Area Redevelopment Administration to undertake the feasibility study. Technical assistance is offered as a means toward stimulating employment in Marshall County which qualifies as a redevelopment area under Section 5 (a) of the Area Redevelopment Act of 1961.

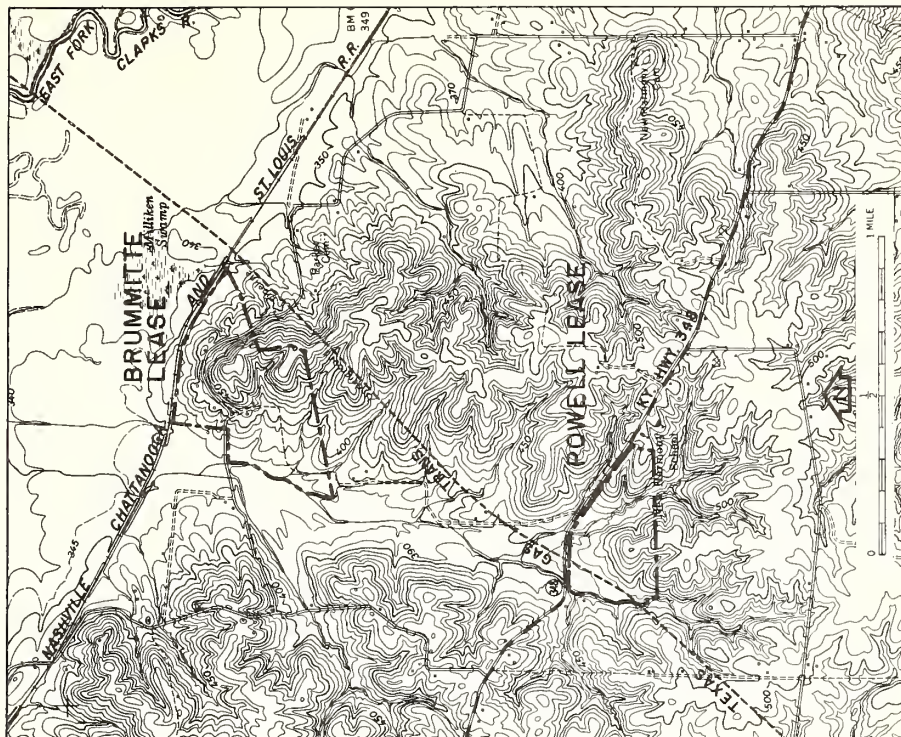
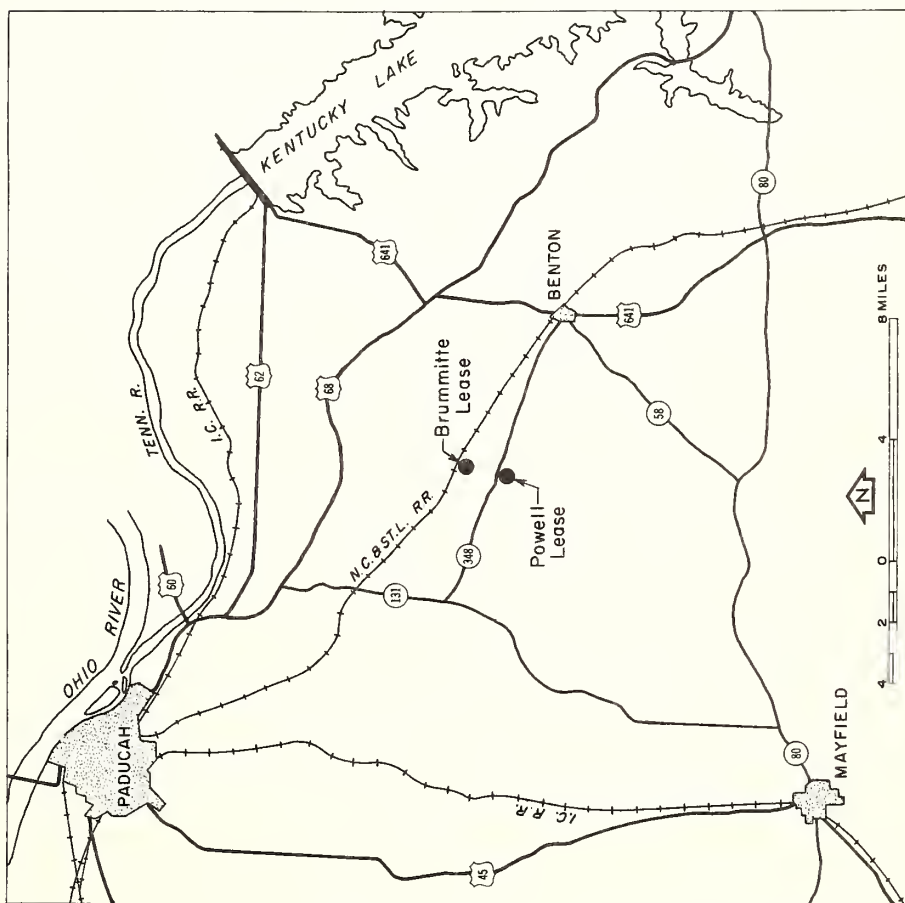
SCOPE

To establish the technical and economic feasibility for a fuller's earth products plant in Marshall County, it was necessary to determine:

- the quality, quantity, uniformity and accessibility of the fuller's earth deposits
- the kinds of products that can be made from the raw materials
- the demand and price for these products
- projected net sales
- the optimum-sized plant to produce the most promising products
- capital requirement for mine and plant
- plant operating costs
- sales costs
- profitability based on the above factors.

A drilling program was required to determine the quantity, quality, uniformity and accessibility of the fuller's earth deposits. Split-spoon and diamond core samples provided materials for the laboratory testing phase of the project.

Figure 1-2
LOCATION MAPS OF
POWELL AND BRUMMITTE LEASES
MARSHALL COUNTY, KENTUCKY



Representative portions of all samples from alternate drill holes were analyzed by X-ray diffraction techniques to determine variations in mineralogy. Selected representative samples were tested for absorption and other physical properties which determine potential uses.

The list of products that can be made from the fuller's earth deposits in Marshall County is quite lengthy. However, the demand for most of these products is very limited. A detailed market survey was required to determine which products have sufficient demand and price to justify building a plant. Because the amount of published data on fuller's earth markets suitable for use in feasibility study is quite limited, primary data had to be collected by the project team. Statistics from the U. S. Bureau of Mines and the Census Bureau constituted the only major secondary sources of information on markets. Cross-sectional studies for all types of distributors and users were made to determine the characteristics of each of the markets for fuller's earth products.

The production methods and financial condition of other fuller's earth producers were studied in order to better understand operating problems of competing companies. Selection of the products that could be made from a single plant was based upon promotional and sales considerations, nature of the raw material, plant efficiency, and packaging problems.

To determine the optimum-sized plant for manufacturing the products selected, a flow sheet utilizing the most satisfactory, proven features developed by other producers and equipment manufacturers was established. Kiln firing schedules, labor requirements, inventory costs, and market size and potential penetration were the primary considerations for establishing the optimum size for a plant.

Profitability analysis is based on a consideration of the three essential elements - capital requirement, operating and sales costs, and net sales - which determine profitability.

STAFF AND ACKNOWLEDGMENTS

The project was performed by Spindletop's Techno-Economics Research Division, under the direction of Theodore R. Broida with the assistance of the Physical Sciences Division under the direction of Wingate A. Lambertson.

The project team consisted of:

William J. Evans, economist (project manager);

Gary R. Gates, economic geologist;

Paul Howell, geologist;

William H. McGuire, geologist; and

James H. Healy, ceramist.

The help and cooperation of the following persons and organizations are acknowledged: Don and Joe Sargent, D. J. Enterprise, Benton, Kentucky, who contributed many helpful suggestions; Standard Core Drilling Company, Somerset, Kentucky, which performed the drilling under the direction of Mr. Howell; Mr. John Stokely of John A. Stokely and Associates, Lexington, Kentucky, whose valuable contributions were incorporated into the drilling and sampling work; W. Doss Lumpkin, who was of valuable assistance in dealing with clay marketing problems in the oil bleaching and clarification field. Cooperation in the fuller's earth trade, both by manufacturers and distributors, was very gratifying. Finally, the assistance of Allis-Chalmers Manufacturing Company, Jeffrey Manufacturing Company, St. Regis Paper Company, Western Kentucky Gas Company, West Kentucky Rural Electric Cooperative Corporation, Louisville and Nashville Railroad Company, and the Kentucky Department of Economic Security, all of whom supplied cost information, is gratefully acknowledged.

Section 2

SUMMARY AND CONCLUSIONS

The purpose of this study is to determine the technical and economic feasibility for establishing a manufacturing plant to produce fuller's earth products in Marshall County, Kentucky.

An extensive clay formation consisting dominantly of montmorillonite crops out in a narrow band from extreme southern Illinois through Kentucky and Tennessee, into Mississippi. At several places, the formation is exploited to manufacture fuller's earth products which are used mainly as oil, grease, and water absorbents on floors. Formerly, the clay deposits served as a major source of natural decolorization and bleaching clays in oil processing industries. However, this use has been declining in recent years.

Fuller's earth deposits of a different type (consisting mainly of the mineral attapulgite rather than montmorillonite) are found in southern Georgia and northern Florida. Fuller's earth products of the attapulgite type command a higher price than absorbents of the montmorillonite type because of more intensive promotion, lower bulk density, higher oil absorption capacity, and lighter color. However, with a lower price, montmorillonite-type fuller's earth can compete for absorbent markets if proper care is exercised in processing and promotion work to minimize these disadvantages.

Soil conditioners and animal litter are manufactured from montmorillonite-type fuller's earth deposits. Soil conditioners consisting of granular montmorillonitic fuller's earth are highly resistant to breakdown in water and are used mainly for golf greens at the present time. Fuller's earth soil conditioners are finding increased use in other soil applications; e.g., football turfs and industrial lawns. The market for cat litter is also growing, and fuller's earth is the most common raw material used to manufacture this product. Other products may someday be profitably developed because of certain properties of montmorillonitic fuller's earth; e.g., filters for treating radioactive water and industrial wastes, and industrial fillers.

In Kentucky, the formation containing fuller's earth is called the Porter's Creek Clay. This report is concerned with two farm tracts located in Marshall County where the Porter's Creek Clay crops out

near gas and electrical lines, transportation facilities, labor supplies, and major U. S. markets.

The physical and chemical properties of fuller's earth deposits from two sites in Marshall County indicate that these clays are suitable for manufacturing bleaching clay, floor absorbent, soil conditioner, and animal litter. Other products are technically possible; e.g., radioactive and industrial-waste filters, and fillers.

Of the two tracts considered, the Brummitte farm provides the most favorable plant site because of better quality of clays and proximity to rail facilities. It is underlain by 1,680,000 tons of measured reserves of fuller's earth which are adequate to sustain plant operation for at least thirty years.

The major risk results from the uncertainty of creating an effective sales organization which can make the most of the marketing opportunities at hand. Proper attention to sales problems, however, should provide sales of approximately 10,000 tons in the first year increasing to 20,000 tons in the fifth year of operation.

The feasibility study indicates that a 60-ton per day plant to produce floor absorbents and soil conditioner is justified. A mechanized plant capable of manufacturing highest quality products at low cost is necessary for profitable operation. A labor-intensive plant, it is concluded, could not return adequate profit in spite of a lower capital requirement.

Section 3

GEOLOGICAL BACKGROUND

The Jackson Purchase area of Western Kentucky is a portion of the physiographic province known as the Upper Mississippi Embayment.¹ Relatively horizontal sedimentary formations of Quaternary, Tertiary, and Cretaceous age form the exposed geologic section in this area. A recent publication by Pryor and Glass describes the mineralogy of these rocks.²

A formation known as the Porter's Creek Clay, predominantly a montmorillonite clay of early Tertiary (Paleocene) age, is present on the two leases under investigation (see Figures 3-1 and 3-2). A comprehensive petrographic report on the Porter's Creek Clay at Olmsted, Illinois (40 miles to the northwest of the Marshall County deposits) was prepared by Grim³ in 1933; chemical analysis of the Olmsted deposits are shown in Table 3-1.

The Porter's Creek Clay has recently been mapped in the geologic mapping program of the Kentucky and U. S. Geological Surveys.⁴ Maps showing water supply characteristics are also available for the area.⁵ Figure 3-3, page 3-4, contains a map showing outcrop of the Porter's Creek and distribution of other clays in the Jackson Purchase area.

¹Fennemon, N.M., Physiography of the Eastern United States, McGraw-Hill, 1938.

²Pryor, W. A., and Glass, H.D., "Cretaceous-Tertiary Clay Mineralogy of the Upper Mississippi Embayment," Journal of Sedimentary Petrology, Vol. 21, No. 1, March 1961.

³Grim, R.E., "Petrography of the Fullers Earth Deposits at Olmsted, Illinois (with a brief study of some non-Illinois earths)," Economic Geology, Vol. 28, No. 4, 1933, pp. 344-363

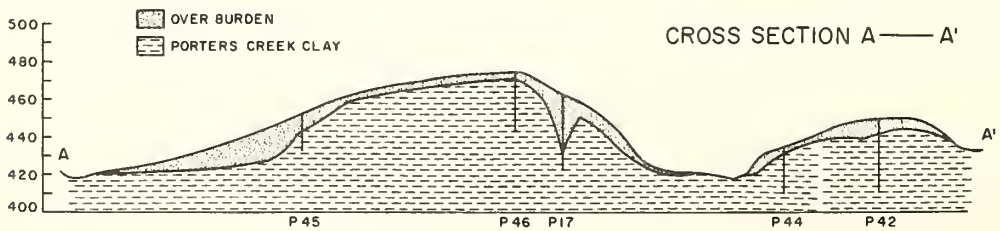
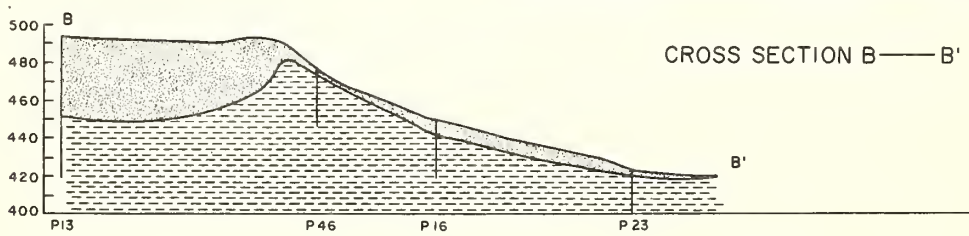
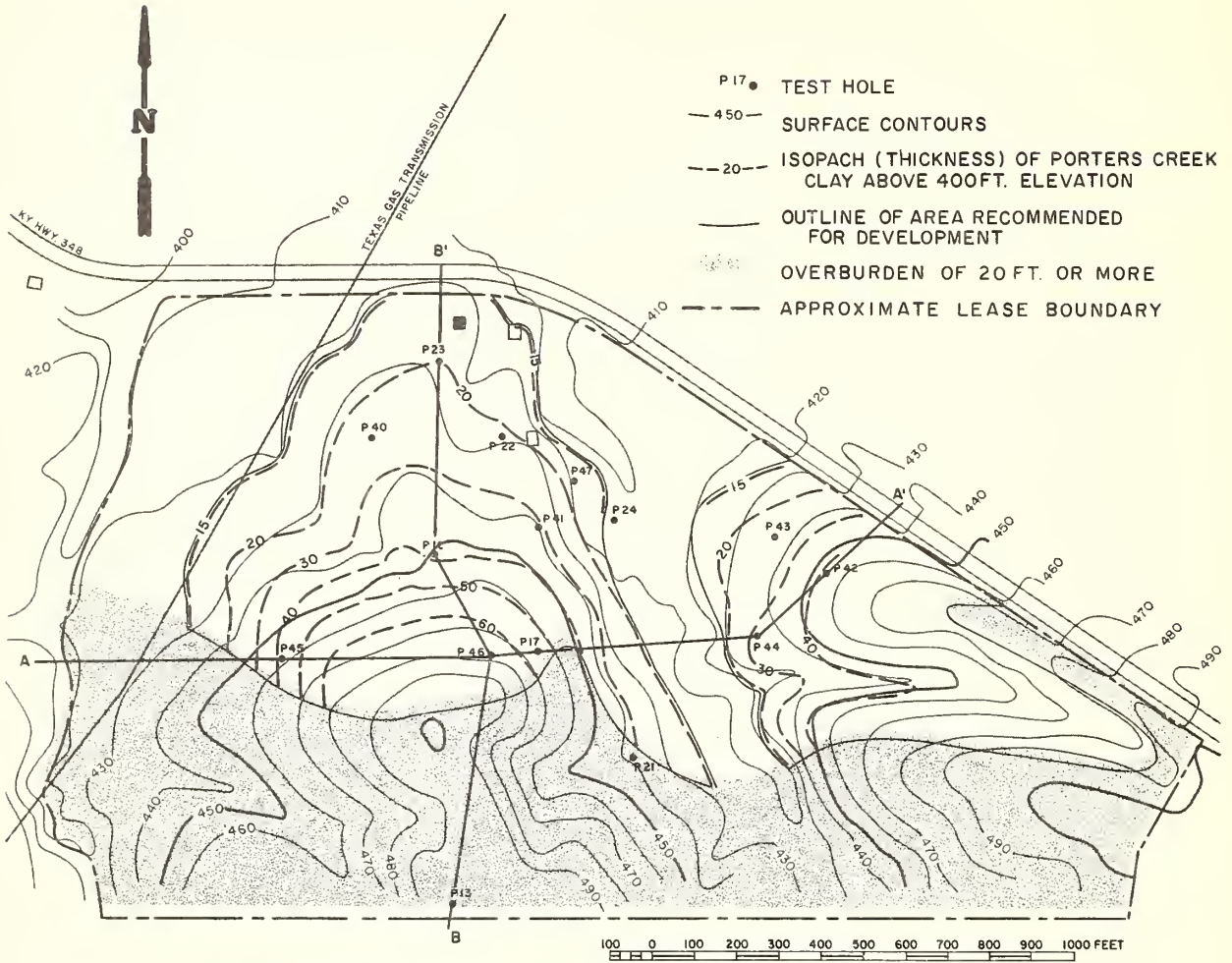
⁴Olive, W.W., "Geology of the Elva Quadrangle, Kentucky," Map GQ-230, U. S. Geological Survey, Washington, 1963.

⁵MacCary, L.M., and Lambert, T.W., "Reconnaissance of Ground Water Resources of the Jackson Purchase Region, Kentucky," Hydrologic Investigation HA-13, U. S. Geological Survey, Washington, 1962.

Figure 3-1

ISOPACH MAP OF PORTERS CREEK CLAY

POWELL LEASE
MARSHALL COUNTY, KY.



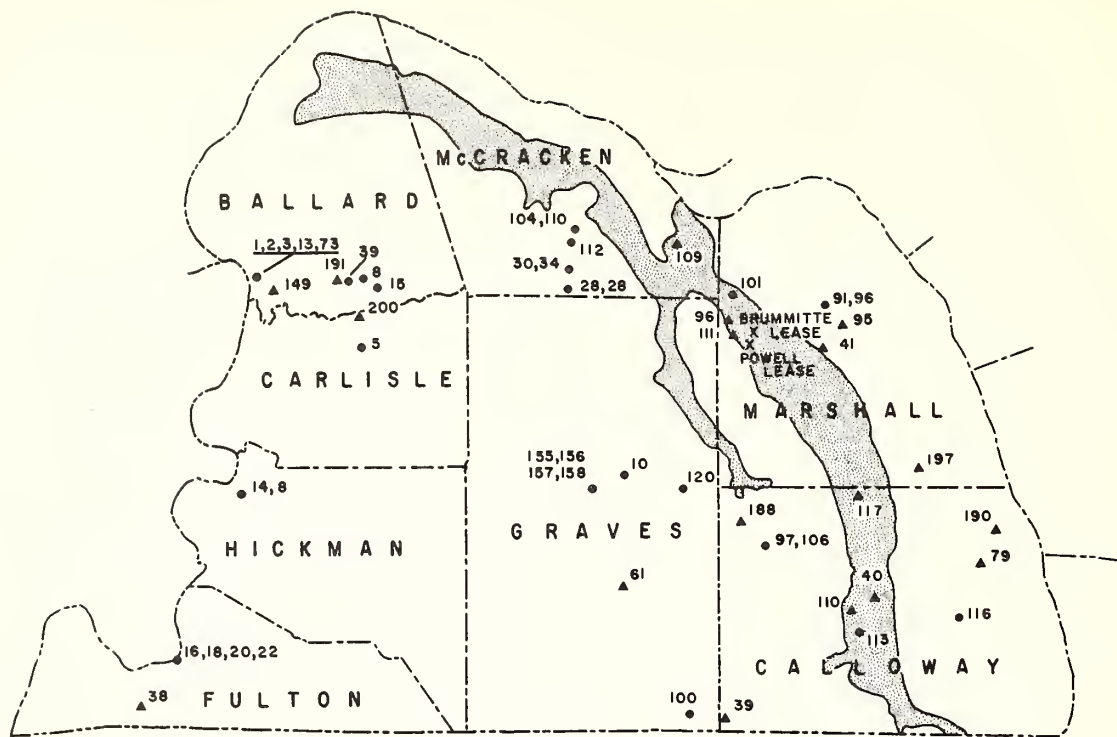


FIGURE 3-3

CLAY SAMPLE LOCATIONS AND PORTERS CREEK CLAY OUTCROP AREA

2. SAMPLE LOCATION AND NUMBER

Source: Easton, H. D., Report on The Technology of Kentucky Clays. Ky. Geol. Survey, 4th Series, Vol. 1, Pt. 2, p. 713-921; 1913

2▲ SAMPLE LOCATION AND NUMBER (Sources listed below)

Samples No. 18 thru 41:

Walker, Frank H., Misc. Clay and Shale Analyses for year 1951-52, Ky. Geol. Survey Report of Investigations No. 6, Series IX; 1953

Samples No. 42 thru 90:

Floyd, Robt. J., and Kendall, Thomas A., Misc. Clay and Shale Analyses for 1952-54, Ky. Geol. Survey Report of Investigations No. 9, Series IX; 1955

Samples No. 91 thru 154:

McGrain, Preston and Kendall, Thomas A., Misc. Clay and Shale Analyses for 1955-56, Ky. Geol. Survey Report of Investigations No. 13, Series IX; 1957

Samples No. 155 thru 205:

McGrain, Preston; Kendall, Thomas A., and Teater, Thelma C., Misc. Clay and Shale Analyses for 1957-59, Ky. Geol. Survey Report of Investigations No. 3, Series X; 1960



OUTCROP OF PORTERS CREEK CLAY

Source: L. M. MacCary, U. S. Geological Survey, Ground Water Branch

Table 3-1

CHEMICAL COMPOSITION OF PORTER'S CREEK CLAY,
IN PULASKI COUNTY, ILLINOIS

Sample	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	Ign.	H ₂ O+	H ₂ O-
1	69.25	-	10.16	3.06	-	2.67	4.32	1.33	2.12	6.98	-	-
2	59.97	0.48	16.44	4.45	0.17	2.09	0.50	0.16	1.21	14.15	14.15	6.72
3	61.3	0.37	15.88	4.51	0.17	2.31	0.56	0.17	0.95	13.84	13.84	5.43
4	64.24	t	14.60	4.59	0.15	1.95	1.26	0.20	1.22	11.73	11.73	5.48
5	59.16	0.49	16.67	3.79	0.21	1.56	1.00	t	1.50	15.23	15.25	6.78
6	61.06	0.21	15.99	4.50	0.12	2.00	0.86	0.07	1.43	13.36	13.36	5.88
7	65.22	0.24	13.86	2.82	2.06	1.76	0.80	0.30	1.03	11.32	11.32	5.67
8	61.67	0.46	15.85	3.40	0.77	2.07	0.58	0.06	1.40	13.12	13.12	4.88
<u>Location</u>												
1.	SW SW SW 7-16S-1W											
2.	Olmsted Standard Oil pit											
3.	Olmsted Standard Oil pit											
4.	Olmsted Standard Oil pit											
5.	NE SE 27-15S-1E											
6.	NE SE 27-15S-1E											
7.	NE SE 27-15S-1E											
8.	NE SE 27-15S-1E											

t = trace

The Porter's Creek is up to 200 feet thick, but is thinner in areas where the overlying Claiborne(?) Formation (Eocene age) or post-Eocene continental deposits have formed along the deeply truncated erosional surface formed in post-Paleocene time.

The region is characterized by numerous small-scale faults and local blocks of steeply dipping sedimentary beds. Because of complex structure and a considerable amount of variation in the depth to which the overlying sediments cut into the Porter's Creek Clay, only close-spaced drilling and careful observation of outcrop features can reveal the distribution, quality, quantity, and accessibility of deposits in the Porter's Creek Clay.

Section 4

FIELD OBSERVATIONS

POWELL LEASE

The Porter's Creek Clay (dark gray to black, montmorillonitic, micaceous, quartz-silty, laminated) is the oldest and lowermost formation outcropping on the Powell lease (Figure 3-1).¹ Minor amounts of silt and fine-grained mica are disseminated throughout the clay, but commonly the silt is restricted to macro-laminae and blebs. Unweathered samples change from black to a medium gray upon drying, are moderately hard, and fracture conchoidally. The lithology is relatively homogeneous both vertically and laterally, although there is a regular transition from weathered to unweathered clays as depth increases. Soft weathered zones near the surface are medium gray and generally stained with limonitic material. The color becomes progressively darker with increasing depth, becoming black at a depth of about 20 feet. Some small micaceous quartz sand dikes are present, but they appear to be less than a foot thick and of undeterminable length. Some limonitic mineralization occurs in and near these dikes from the circulation of chalybeate waters, but oxidation does not occur below six inches due to the impermeable nature of the clay.

The Porter's Creek Clay rests conformably on the unexposed Clayton(?) Formation (Upper Cretaceous and Paleocene (?) age) and is overlain unconformably by the Claiborne (?) Formation (Eocene age) and post-Eocene continental deposits. The surface of the Porter's Creek Clay is an undulating erosional surface with up to 40 feet of relief. The remnants of a post-Porter's Creek channel, filled with post-Eocene continental sand and gravel deposits, form thick overburden trending east-west on the south half of the property. The least amount of overburden is on the northern half of the lease. The highest postulated occurrence of clay is 480 feet elevation; the lowest elevation penetrated, 360 feet (hole B-47), was all Porter's Creek Clay. Thus, the formation is at least 120 feet thick here. Projecting the base from the Brummitte lease on a regional dip of 30 feet per mile, it would probably be encountered at 390-400 feet.

¹All drilling logs are reproduced in Appendix A.

The Powell lease is underlain by 1,500,000 tons of measured reserves on 25 acres with less than 20 feet of overburden and by a considerable amount of indicated reserves under thicker layers of overburden.

BRUMMITTE LEASE

The Porter's Creek Clay is the oldest and lowermost outcropping formation on the Brummitte lease (Figure 3-1).¹ The lithology is similar to that described on the Powell lease but with an increase of silt and fine-grained mica in the lower 30 feet. The clay mineral composition of the less-than-two micron fraction of samples from the Brummitte lease is characterized by less illite and kaolinite and more montmorillonite than samples from the Powell lease. Gravel encountered in clay similar to Porter's Creek Clay in the lower portion of hole B-16 (see Appendix A) is probably younger, reworked material.

On Block 1 (the area north of and adjacent to the ridge road), the contact with the underlying Clayton (?) Formation occurs at approximately 360 feet elevation along the north edge of the Brummitte lease. This contact does not represent the general elevation of the contact on the rest of the lease because of the dip of clays and faulting through this horizon. The highest elevation of Porter's Creek Clay is 460 feet; thus, total thickness is less than 100 feet. On Block 1, slight to steep (30°) dips were recorded in cores taken on the north side of the gravel road in holes B-15 and B-19. Slight dips were observed in places in holes B-14 and B-31 high on the hill north of the road.

Numerous slickensides were present in all core and split-spoon samples. An area underlain by thick overburden trending north-westward on the north side of the road can be interpreted either as a channel fill or as a feature caused by faulting. Overburden 45 feet or thicker is present on the down-dropped side north of this fault and may be flanked by a parallel fault 175 feet north of the one mapped. Due to this fault, no commercial deposit can be expected on the side of the hill below the fault above local drainage. Displacement can not be determined from drill data but is estimated to be 40 or 50 feet. Another abrupt feature centers around hole B-30, which penetrated 37 feet of gravel, sand, and clay without reaching the Porter's Creek Clay. Here the overburden

¹All drilling logs are reproduced in Appendix A

is limited in extent as determined by surface mapping; it may represent a downfaulted block or channel fill of post-Eocene continental deposits.

The Brummitte lease contains an estimated 1,680,000 tons of measured reserves with less than 20 feet overburden on one tract (Block 1) totaling 21 acres. Reserves include clay above 365 feet elevation only. In addition to these measured reserves, indicated reserves on the west side of the ridge (1,500,000 tons) have been estimated on the basis of published information.¹ Block 2 (166,000 tons indicated reserves), an oval shaped outcrop 100-150 feet uphill from Block 1, apparently is separated from Block 1 by relatively thick overburden.

¹ Olive, W.W., op. cit., p. 3-1

Section 5

CLAY SAMPLING AND TESTING

DRILLING METHODS

Several techniques (augering, coring, and split-spoon sampling) were employed in drilling for clay samples. Hole locations are marked on Figures 3-1 and 3-2. Table 5-1 shows the techniques used and total depth of all holes on both leases (Raymond Powell farm and J. D. Brummitte farm).

Auger and split-spoon samples were taken in soft, weathered clay where coring was not feasible. Harder, unweathered clays were cored, with an average recovery of 90%. Sand and clay overburden was drilled with an auger or with a fish-tail bit. Of the 29 holes, portions of 14 were cored, and portions of 12 holes were sampled with a split-spoon. Augering, for additional control, was used to drill 14 holes and to start all but one hole.

After drilling six exploratory holes on the Brummitte lease and finding excessive overburden (over 20 feet), a change was made in the drilling plan; i.e., 14 test holes were drilled in a concentrated area rather than the 25 to 30 holes originally planned. Detailed sample descriptions are included in Appendix A.

TESTING PROCEDURES

The Marshall County clay from the Brummitte and Powel leases was evaluated by first determining which areas on the two leases could best be mined. Representative samples for testing were taken from cores (each sample representing about ten feet) selected on the basis of quantity and accessibility of reserves (about one-half of all holes were sampled). These holes are described in Appendix A. Each sample was analyzed using the X-ray diffraction technique because the structural features of the clay minerals determine most of the critical properties of the fuller's earth products under evaluation. In addition to X-ray analyses, the following tests were performed on selected clay samples: decolorization, oil retention, resistance to breakdown by water, apparent density, slaking test, and response to heat and acid treatment. The tests and general laboratory techniques are described in Appendix B.

Table 5-1

DRILLING RESULTS

POWELL LEASE				BRUMMITTE LEASE			
Hole	Technique *	Total Depth (Feet)	Overburden (Feet)	Hole	Technique *	Total Depth (Feet)	Overburden (Feet)
P-13	A&C	75	43	B-2	A	20	20
P-16	A, S&C	32	9	B-6	A	20	20
P-17	A&C	40	30	B-7	A	20	3
P-21	A	23	23	B-9	A	20	20
P-22	A&C	20	3	B-11	A	36	7
P-23	A, S&C	26	3	B-13	A, S&C	45	45
P-24	A	15	7	B-14	A, S&C	70	4
P-40	A, S&C	20	5	B-15	S&C	35	0
P-41	A	26	0	B-16	A, S&C	15	5
P-42	A	39	6	B-18	A	21	20
P-43	A	31	10	B-19	A, S&C	35	0
P-44	A	25	8	B-20	A	27	0
P-45	A	20	17	B-30	A&S	37	37
P-46	A, S&C	30	4	B-31	A, S&C	60	1
P-47	A, S&C	74	1				
15 Holes				14 Holes			

*A- Augered
 C- Cored
 S- Split-spooned

RESULTS

Basic Properties

Representative X-ray patterns for untreated, glycolated, and heated samples of the less-than-two micron fraction are shown in Figure 5-1. These traces, and traces for unfractionated samples, show that the Porter's Creek Clay is composed dominantly of montmorillonite, kaolinite, illite, and mixed-layer clay minerals, plus quartz, mica, and feldspar. The last three minerals are the primary coarse constituents in the Porter's Creek Clay.¹

Samples from the Brummitte lease have greater decolorization power than samples from the Powell lease taken near the surface (Table 5-2). Only the clay below 15 to 25 feet in Powell samples have high decolorizing power.

Brummitte samples have decolorizing power equal to, or greater than, the American Oil Chemist Society standard natural sample, and comparable power to two acid-activated bentonite samples (BC 75, and Special Filtrol).² Brummitte clay samples have an average light transmission³ of 94 percent and oil retention of 41 percent by weight.

There is a correlation between decolorizing power and the ratio of montmorillonite to other clay minerals.

¹The chief variations in samples are larger amounts of 7-Angstrom material (kaolinite peaks at 12.4 degrees in Figure 5-1) and 10-Angstrom material (illite and mica peaks at 8.8 degrees in Figure 5-1) in samples from the upper part of the Porter's Creek on the Powell lease, and smaller amounts of these materials from samples from the Brummitte lease. The relative amounts and character of montmorillonite are illustrated in Figure 5-1 (peaks at 6.2 degrees on trace number 1 and about 5 degrees on trace number 2). Montmorillonite from the Porter's Creek Clay does not yield sharp diffraction peaks. This is probably due to poor crystallization and orientation. Thicker slides resulted in sharper diffraction peaks for montmorillonite than the ones shown in Figure 5-1.

²Commercial product trade names.

³Appendix B, Decolorization.

Figure 5-1
TYPICAL X-RAY DIFFRACTION PATTERNS FOR
CLAY-FRACTION OF PORTERS CREEK SAMPLES

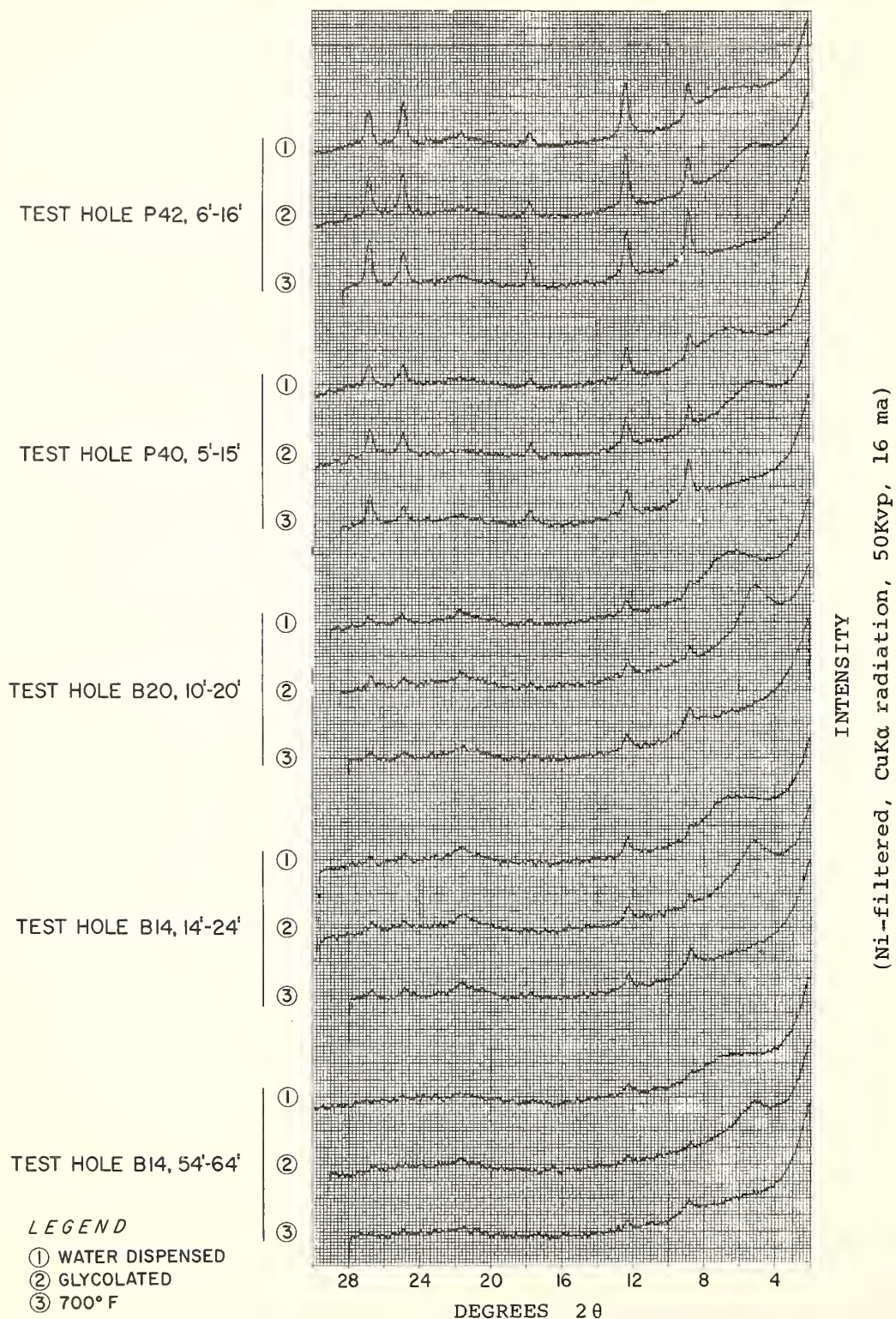


Table 5-2

DECOLORIZING POWER AND OIL RETENTION
(Percent Transmission - 100% = pure benzene)

		Percent Crude Soybean Oil to Sample ¹					Percent Retention
		30	60	90	120	180	
Crude Soybean Oil			7				
AOCS Natural Bleaching Clay		97	93	91	90		31.3
AOCS Acid Activated Clay			95		91	87	38.5
Acid Activated							
Bentonite (BC-75) ²			91		84	77	31.4
Special Filtrol ³			96				39.0
Hole	Depth (Feet)						
P-16	9-19		89				49.4
P-16	19-29		92				56.8
P-16	29-32		92				58.2
P-23	3-13		86				34.8
P-23	13-23		93				58.2
P-23	23-26		90				56.4
P-40	5-15		83				33.1
P-40	15-20		88				44.0
P-41	6-16		86				33.1
P-41	16-26		88				36.5
P-42	6-16		66				29.2
P-42	16-26		88				33.8
P-42	26-36		90				31.8
P-42	36-39		95				37.0
P-46	3 1/2-12	90	79	56			25.7
P-46	12-23	97	92	93			55.4
P-46	23-30	100	86	92			60.6
B-14	4-14		92		70		36.2
B-14	14-24		93		90		49.8
B-14	24-34		95				30.8
B-14	34-44		92				36.4
B-14	44-54		97				42.2
B-14	54-64		95				42.6
B-14	64-70		94				45.1
B-15	0-11		95				45.3
B-15	11-20		94				49.3
B-15	20-31		97				48.1
B-15	31-35		90				44.7
B-19	0-10		94				35.7
B-19	10-20		93				46.2
B-19	20-30 1/2		93				47.8
B-20	0-10		93				37.2
B-20	10-20		93				33.8
B-20	20-27		92				32.1

¹Weight Soybean Oil/Weight Clay X 100

²Trade Name Bennett-Clark Co.

³Trade Name Filtrol Corp.

The less montmorillonite and the more kaolinite, illite, quartz, mica and feldspar contained in samples, the lower the decolorizing power.

Chemical analyses for samples of Porter's Creek Clay in the vicinity of the Marshall County deposits are shown in Table 3-1. Two composite samples suitable for chemical analyses have been prepared and are being sent to D. J. Enterprise in the event that some future use for fuller's earth may require analysis of uncalcined, pit-run Porter's Creek Clay. A composite sample for Hole No. B-14 was made by adding 4 grams each of ground representative samples from 4-14 feet, 14-24 feet, 24-34 feet, 44-54 feet, and 54-64 feet, and 2.4 grams from 64-70 feet. A composite sample for Hole No. P-42 was made by adding 8 grams each of ground representative samples from 6-16 feet, 16-26 feet, and 26-36 feet, and 2.4 grams from 36-39 feet.

Response to Treatment

Trends based on heating three samples of clay with low decolorizing power to 1200°F show that decolorizing power and oil retention are enhanced by calcining (Table 5-3).

Table 5-3

EFFECT OF HEAT TREATMENT ON DECOLORIZING POWER, OIL RETENTION, AND WATER BREAKDOWN

Hole	Depth (Feet)	Percent Light Transmission (60% Oil)		Percent Oil Retention			Percent Water Breakdown ¹
		Natural	1200°F	Natural	700°F	1200°F	
P-42	6-16	66	97	29.2	38.2	38.0	0.67
P-40	5-15	83	97	33.1	43.5	47.8	0.67
B-20	10-20	93	98	33.8	42.3	51.8	0.67
B-14	14-24	93	100	49.8	58.5	61.2	0.67
B-14	54-64	95	100	42.6	59.5	60.8	2.00

¹ Samples heated to 1200°F

Based on limited data, it was found that acid treating those clays characterized by low decolorizing power increases the decolorizing power and decreases oil retention (Table 5-4).

Table 5-4

EFFECT OF HEAT TREATMENT AND ACID TREATMENT
ON DECOLORIZING POWER AND OIL RETENTION

Sample	Depth	Treatment	Percent Crude Soybean Oil to Sample*					Percent Retention
			30	60	90	120	180	
P-46	3.5'-12'	Nat.	90	79	56			25.7
P-46	12'-23'	Nat.	97	92	93			55.4
P-46	23'-30'	Nat.	100	86	92			60.6
P-46	3.5'-12'	1200°F	94	88	75			25.8
P-46	23'-30'	1200°F	96	95	92			
P-46	3.5'-12'	Acid		93		79	48	25.3
P-46	13'-23'	Acid		90		88	82	48.2
P-46	23'-30'	Acid		93		88	83	52.5

* Weight Soybean Oil/Weight Clay X 100

On the basis of density tests carried out according to federal specifications,¹ the bulk density of montmorillonite-type fuller's earth is greater than for attapulgite-type fuller's earth (Table 5-5).

Montmorillonite clays from the Brummitte lease, when heated to 649°C (1200°F) have a lower water breakdown rate (0.67 to 1.67 percent) than for attapulgite (greater than 3.0 percent).

Heating the Brummitte and Powell clays to 649°C in an oxidizing atmosphere imparts a distinctive reddish color because of the iron content. The oxidized iron should not greatly affect oil retention, water breakdown, or decolorizing power of the clay.

¹ GSA-FSS; P-S-008656

Table 5-5

SCREEN ANALYSIS, BULK DENSITY, AND
PERCENT BREAKDOWN IN WATER

Sample	Screen Analysis (%)					Bulk Density	Percent Breakdown
	6-10	10-30	30-40	40-60	60-100		
Hi Dri ¹	5.7	75.4	9.9	6.5	1.6	29.7	2.7
Zorb All ²	34.0	52.6	5.7	6.5	1.1	39.1	1.67
Thompson ³	8.3	75.5	11.1	4.1	0.5	37.1	3.0
VaniSorb ⁴	1.5	86.5	7.2	3.1	0.8	28.7	3.0
B-19, 0'-10' ⁵			73.0	17	10	49.4	1.67
B-15, 0'-11' ⁵			73.0	17	10	45.6	1.67
B-14, 34'-44' ⁶	34.0	52.6	14.0			41.6	
B-14, 34'-44' ⁶	25.2	70.5	3.7	0.6		36.7	

¹Trade Name, Waverly Petroleum Products Co.

²Trade Name, Wyandotte Chemical Corp.

³Floor Absorbent obtained from Thompson Chemical Supply Co., Lexington, Kentucky.

⁴Trade Name Dameron Enterprises, packaged by Minerals and Chemicals, Phillipp Corp.

⁵Calcined at 370°C (700°F)

⁶Calcined at 649°C (1200°F). Sample B-14, 34'-44' was ground to two different size gradations to illustrate relation of bulk density to particle-size distribution.

However, it has been reported¹ that the Fe_2O_3 is responsible for the oxidation of the acids in oils during decolorization. Acid solution of the Fe_2O_3 can be accomplished commercially.

Heating the clays to 700°F and 1200°F increases the oil retention. For example, a sample from the interval between 70 and 73.3 feet in hole P-13 gave 66 percent oil retention in the raw state, 71 percent after heating to 700°F, and 77 percent after heating to 1200°F.

The effect of heat treatment on the percent of oil retention of other samples is shown in Table 5-3. In some samples, oil retention is nearly the same for heat treatment at 700°F and 1200°F. Prolonged heating at 1200°F might result in higher values of oil retention for these samples.

¹Miller, J. G., Haden, W.L. Jr., and Oullon, T.D., The Oxidizing Power of the Surface of Attapulgas Clay, 1963, oral presentation, 12th National Clay Conference Meeting.

Section 6

TECHNICAL PRODUCT EVALUATION

BLEACHING USES

Test results indicate that the bleaching or decolorizing properties of the fuller's earth deposits on the two leases in Marshall County are suitable for bleaching vegetable oils. Because vegetable, mineral, and animal oils often yield similar results, the clay will, in general, bleach all three types of oil.

For the samples tested, decolorization generally is as high or higher than the standards specified by the American Oil Chemists Society. Even though decolorization power compares favorably with some commercial acid activated bentonite, the efficiency of the latter may be up to five times greater because of lower oil retention.¹ Because of the high oil retention of fuller's earth and the trend in the oil industry towards the use of activated bentonite, the use of Porter's Creek Clay for bleaching would be limited. Low oil retention is important to minimize oil lost during processing.

Because the specifications for granular agents used in percolation bleaching and minus-200 mesh agents used in contact bleaching are very similar, the Porter's Creek Clay would serve either application equally well.

ABSORBENT USES

The absorbent properties of processed clay are different when made in a modern large scale plant than when processed and tested in the laboratory. For example, reliable bulk density determinations cannot be made on the basis of laboratory tests because results vary with grain-size distribution produced by commercial-scale processing equipment. The following product discussions are based on an interpretation of laboratory test results and composition of the clays; large scale production factors have been considered on a theoretical basis.

¹Rich, A.D., "Bleaching Clay," Industrial Minerals and Rocks, American Institute of Mining, Metallurgical and Petroleum Engineers, New York, 1960, pp. 93-101.

Floor Absorbents

Because high oil absorbtion or oil retention is desirable in floor absorbents, the Porter's Creek Clay has served as a raw material for this use for many years. Resistance to water breakdown compares favorably with products now sold for floor absorbent use. Bulk density for laboratory samples ranges from 36.7 pounds per cubic feet for properly graded material to 49.4 pounds per cubic foot for material with a high percentage of fines. According to Federal Specification P-S-865a, the apparent density (or bulk density) must not exceed 35 pounds per cubic foot. However, some floor absorbents presently sold are higher than 35 pounds per cubic foot. It should be possible, by adjusting gradation of particle size, to approach a bulk density of 35 pounds per cubic foot although the fineness requirements of P-S-865a will not be met.

Animal Litter

The requirements for an animal litter (used almost entirely for cats) are easily met by the Marshall County clay. Absorption of gaseous odors as well as liquids is important in this application. There are no known published specifications for this product. Commercial litter products vary in method of processing, particle-size distribution, and color, but all receive satisfactory acceptance.

OTHER USES

Soil Conditioner

Porter's Creek Clay from other areas is made into a product suitable for soil conditioning. Soil conditioners are still in the development stage although their application on golf course greens is already established. High absorbing capacity and high resistance to breakdown in water are required. Tests show that a satisfactory product can be made from clay on either the Powell or Brummitte farm. It appears that soil conditioner is one of the few products that montmorillonite-type fuller's earth offers superior quality over attapulgite-type fuller's earth.

Radioactive Filtering

Fuller's earth filters radioactive contamination such as fallout (radioactive isotopes of cesium, strontium, etc.) from water and other liquids satisfactorily in laboratory tests. However, most clays and soils and many other materials perform with comparable filtering abilities. No specifications have been developed as yet for radioactive-filter materials.

Fuller's earth offers one advantage over most other materials -- superior resistance to breakdown in water. If water supplies ever reach dangerous levels of radioactivity because of fallout, filters made of fuller's earth may prove satisfactory as a material for use in low-cost purification systems.

Radioactive Waste Disposal

A process described under U.S. Patent 2,717,696 (assigned to the U.S. Atomic Energy Commission) specifies the use of fuller's earth as an absorbent for treating radioactive reactor waste. Because costly organic solvents and diluents are soaked up and are not recoverable, this process is impractical to use.¹

The trend in waste disposal is to reduce the volume as much as possible by evaporation or ion exchange, discharge the harmless effluent by simple disposal means, and fix the high activity portion in some insoluble form which can be safely stored permanently. Therefore, fuller's earth is unsuitable for disposing of reactor waste products.

Drilling Mud

Many different types of clays and additives are used as drilling muds. Often several will be used in drilling one hole due to specific properties that different clays possess. Attapulgit, for example, has had moderate success as a drilling mud in salt water when other clays tend to flocculate.

Scarcely any use has been made of the montmorillonite-type fuller's earth clays in drilling-mud applications. Although Wyoming bentonite (the most widely used drilling mud in the U.S.) is also composed of montmorillonite, it is of a different type with unique properties. The Porter's Creek Clay has never been widely used as a drilling mud and possesses no known unique properties which would make its acceptance likely. Considerable research would be required to develop a commercial drilling mud from the Porter's Creek.

Water Purification

Clays are generally used in water purification to increase settling rates and filterability of undesirable constituents by forming floccules that absorb colloidal wastes. Wyoming bentonite and

¹J.W. Nehls, U.S. Atomic Energy Commission, written communication.

attapulgitite have been used for this purpose and perform satisfactorily. In laboratory tests, Porter's Creek Clay forms a weak floccule using hard water. Bentonite forms stronger floccules and disperses better, making it better suited for purifications than the Porter's Creek Clay.

Industrial Waste Disposal

Various industrial wastes are treated with bentonite and attapulgitite in the same way as described above under water purification. Pulverized fuller's earth from Marshall County would probably not compete with bentonite because of the difficulty of dispersing and flocculating the particles. (See Olin and others for a description of this use for bentonite.)¹

There is a possibility, however, that beds of granular fuller's earth with a carefully-controlled size distribution might find use in treating wastes by a percolating method substituting fuller's earth for part or all of a sand bed. Calcined fuller's earth from Marshall County is resistant to breakdown in water and forms strong granules.

It is suggested that the National Council for Stream Improvement, Inc., 271 Madison Avenue, New York, be contacted by an official of the proposed plant to thoroughly investigate the possibility of using calcined granular fuller's earth beds to filter "color" from pulp and paper mill wastes. "Color" which is dominantly lignin and tannin, is the chief waste problem in some mills because effective and economical methods for removal have not kept pace with removal of suspended solids or biochemical oxygen demand (BOD) improvement. The Council "was organized to develop, through research, solutions to the pulp, paper and paperboard industry's waste disposal problems and to make those findings available to (manufacturer) members for application in actual mill operations."²

Various other industrial wastes might be treated with a granular filter-bed. It is difficult to make generalizations about the many types of industrial wastes; however, fuller's earth might

¹Olin, H.L., Box, R.J., and Whitson, R.E., "Bentonite as a Coagulant for Sewages and Industrial Wastes," Water Works & Sewerage, Dec., 1942.

²"Key to Effective Pollution Abatement," National Council for Stream Improvement, 1960.

be considered in any situations where using an absorption method is appropriate.

Pesticide Carriers

The attapulgite-type fuller's earth found in south Georgia and north Florida is used widely as both dust and granular pesticide carriers. Attapulgite is specified by name in the Federal Specifications for granular pesticides.

Many clays can be used for dust pesticides carriers. The desirable properties are low bulk density (around 30 pounds per cubic foot) plus good absorption of chlorinated hydrocarbons or other active agents. Porter's Creek Clay has not been widely used for pesticide carriers due to its high bulk density. Since pesticides are sold by the pound, a low density carrier fills a container more completely than a high density carrier. Color is also an important factor. Light materials are preferred over the darker gray colors characteristic of the unweathered, uncalcined Porter's Creek. Thus, the Porter's Creek Clay is technically poorly suited for pesticide use.

Miscellaneous Fillers

Clay fillers are used in the manufacture of many products. The filler adds necessary weight or bulk without affecting the desirable characteristics of the product. Fertilizer and feed are examples. Color, pH, density, flowability, toxicity, and other properties are often critical. One of the most important factors is proximity to a large consumer to maintain low freight costs required to be competitive. Filler purchases are generally negotiated on an individual basis. Prime considerations are technical services offered and costs, physical properties, and uniformity, established by each user; Porter's Creek Clay would be suitable for some uses. In many cases, the filler requirements are trade secrets. If various grades of Porter's Creek Clay are distributed to formulators who might use the material as a filler, suitable applications might be found.

Light-Weight Aggregate

Tests conducted by U.S. Bureau of Mines,¹ Illinois State Geological Survey, and A & H Materials Testing Corporation show that the Porter's

Six samples of fuller's earth from the leased farms showed negative floating tests according to Norris Research Laboratory reports for samples 1472 A through F, dated 9-20-62.

Creek Clay does not bloat naturally for making a suitable light-weight aggregate. In areas that contain no suitable natural bloaters, it is possible to use relatively expensive processes for inducing bloating with additives such as coal dust. However, the artificial bloaters could not command a price high enough to justify production because competitors in southern Indiana and northern Kentucky utilize excellent bloating clays, which produce light-weight aggregates cheaply. A number of other materials in western Kentucky, particularly some of the Pennsylvanian-age shales, are more suitable than the Porter's Creek for light-weight aggregate production.

Blending Clay for Ceramic Uses

One of the project responsibilities was to assemble all information on clay resources in the Jackson Purchase Area, and determine whether Porter's Creek Clay could be used for blending purposes with other clays. Figure 3-3 shows the distribution of samples for which there are published analyses. The legend on the map provides a key to locating analyses, descriptions and thickness for various clays in the map area. In addition to these analyses, a comprehensive report by the Kentucky Geological Survey¹ includes a lengthy description of the clays and mining activities in the Jackson Purchase Region. Selling the fuller's earth reserves for \$2 to \$2.50 per ton for blending purposes would not be advisable if a plant to produce absorbents is constructed. These reserves are more valuable to the manufacturer when left in the ground because the value of the plant is partly a function of the amount of reserves at the plant site. In addition, the bulk of the reserves are unsuited for most blending purposes. Even if the better clays were selectively mined, it would be hard to find buyers who require blending clays of this composition. Therefore, it is probable that no opportunity exists for profitable sales of raw blending clays from either fuller's earth deposit under study.

¹ Roberts, J.K., Gildersleeve, B., and Freeman, L.B., 1950, Geology and Mineral Resources of the Jackson Purchase Region, Kentucky: Kentucky Geological Survey Bull. 4, Ser. IX, 114 p., maps.

Section 7

MARKET ANALYSIS

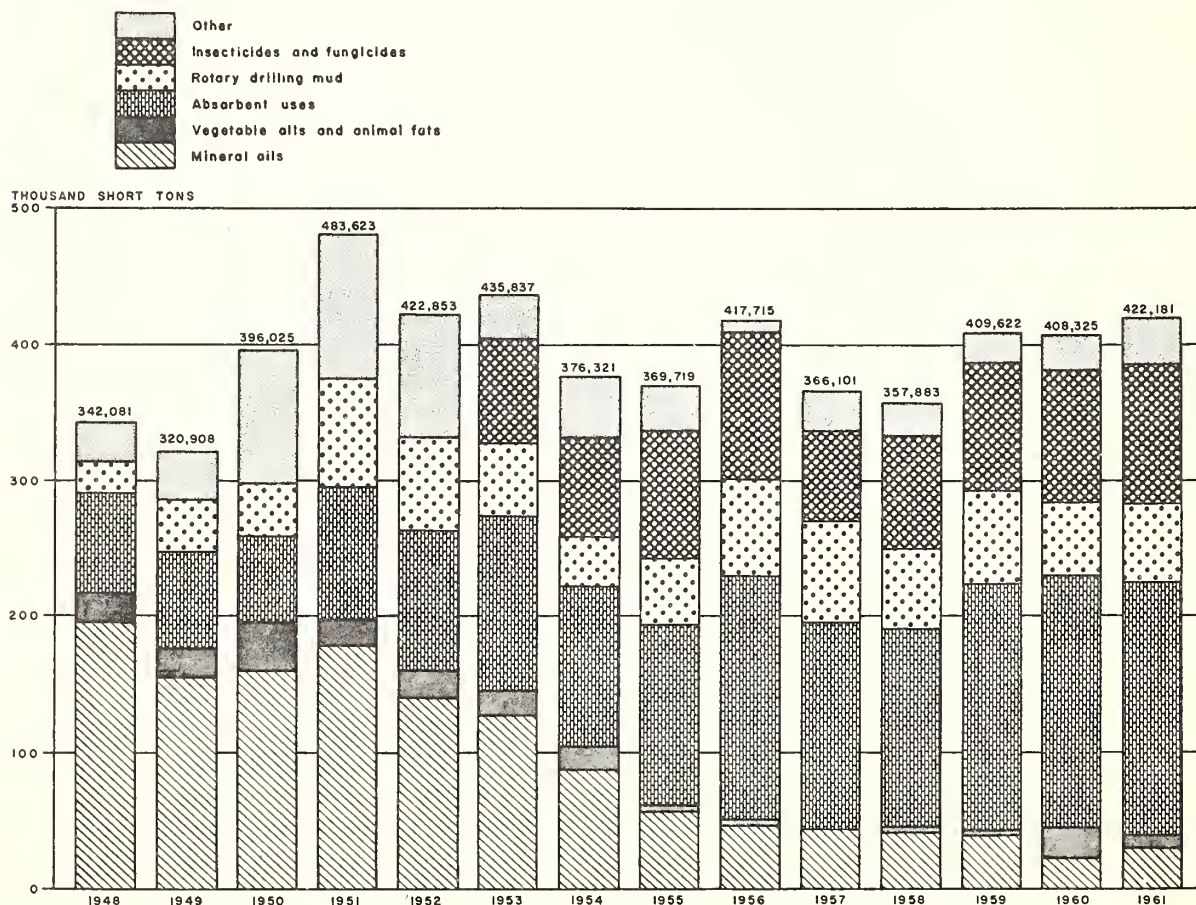
The most complex problem in the feasibility study was to produce an accurate and realistic appraisal of marketing conditions to serve as a basis for economic analysis. The original plan was to intensively study eight cities and supply names and addresses of distributors in these cities together with sales estimates for each of the numerous products that possibly could be made from the clay under study. However, it was discovered that fuller's earth products are involved in what amounts to very keen national competition rather than well-defined regional competition. In fact, the combined totals of all fuller's earth products sold, even with 100 percent market penetration, in the eight cities originally designated would not be great enough to justify building a 50 TPD plant, which is considered the minimum size plant that can operate efficiently.

Therefore, the market was analyzed more from the viewpoint of significant technical factors and distribution characteristics than from the customer identification approach.

Because only a few main products can be efficiently produced at the outset of production for a new plant due to widely varying processing techniques for the possible products, the first step in the market study was to determine which products have growing markets that might be penetrated by a new supplier. The second step was to determine the suitability of the Marshall County clay for making these particular products by comparing technical and marketing factors. The third step was to expand the understanding of the marketing problems for the products selected by exploring in depth the details of pricing and discounting, promotion, manufacturer services, and methods of marketing and distribution. The detailed insights determined in the last step are used as a basis for establishing feasibility and making specific marketing recommendations. Thus, the negative feasibility determination for a plant based solely on the markets provided by the eight cities originally designated transformed into an economically feasible one for a plant when feasibility was based upon evaluation of larger marketing areas.

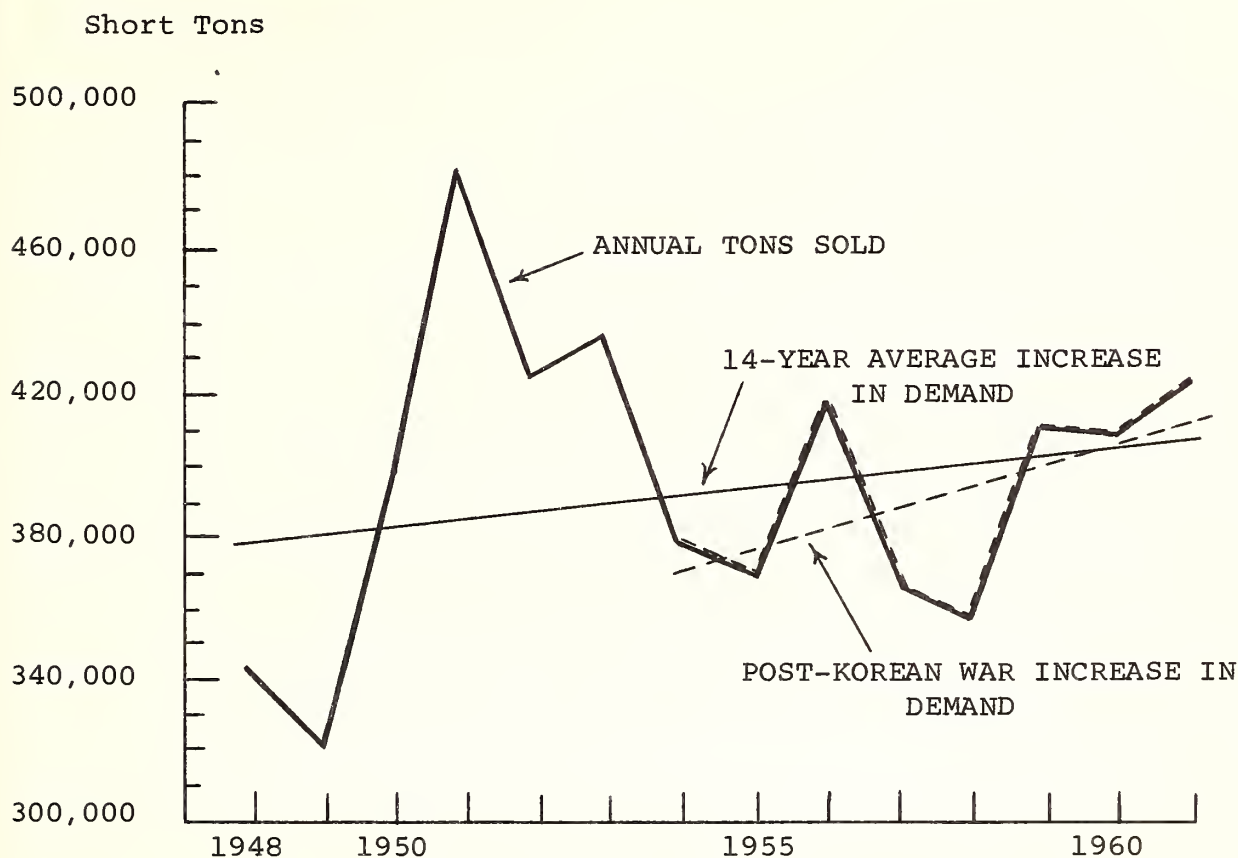
GENERAL OUTLOOK FOR FULLER'S EARTH PRODUCTS

The demand for fuller's earth products has slowly increased since 1948 (Figures 7-1 and 7-2). A least-squares line fitted to annual consumption figures for this period shows an annual increase of 0.45 percent. Greater demand during the Korean War probably was due to the generally higher level of business activity characteristic of the nation's economy at that time. The increase for the period after the Korean War (1.46 percent) shows consumption advancing faster than for the late 1940's.



SOURCE: Minerals Yearbook

Figure 7-1
FULLER'S EARTH SOLD OR USED BY PRODUCERS
FOR SPECIFIED USES, 1948-61



$$1y = 394,942 + 1,765X \quad (\text{origin at } 7/54)$$

$$2y = 390,983 + 5,733X \quad (\text{origin at } 7/47)$$

Source: Minerals Yearbook, 1961

In 1961, 422,151 short tons of fuller's earth were produced at a total value of \$9,518,238¹. The average price for fuller's earth products in the 14-year period from 1947 to 1961 increased 3.5 percent annually (Figure 7-3).

The principal reason for this increase was due to greater use of higher-priced absorbents and a decline in sales of lower-priced bleaching clays (used in raw, uncalcined state).

¹Minerals Yearbooks for 1961, Volume 1

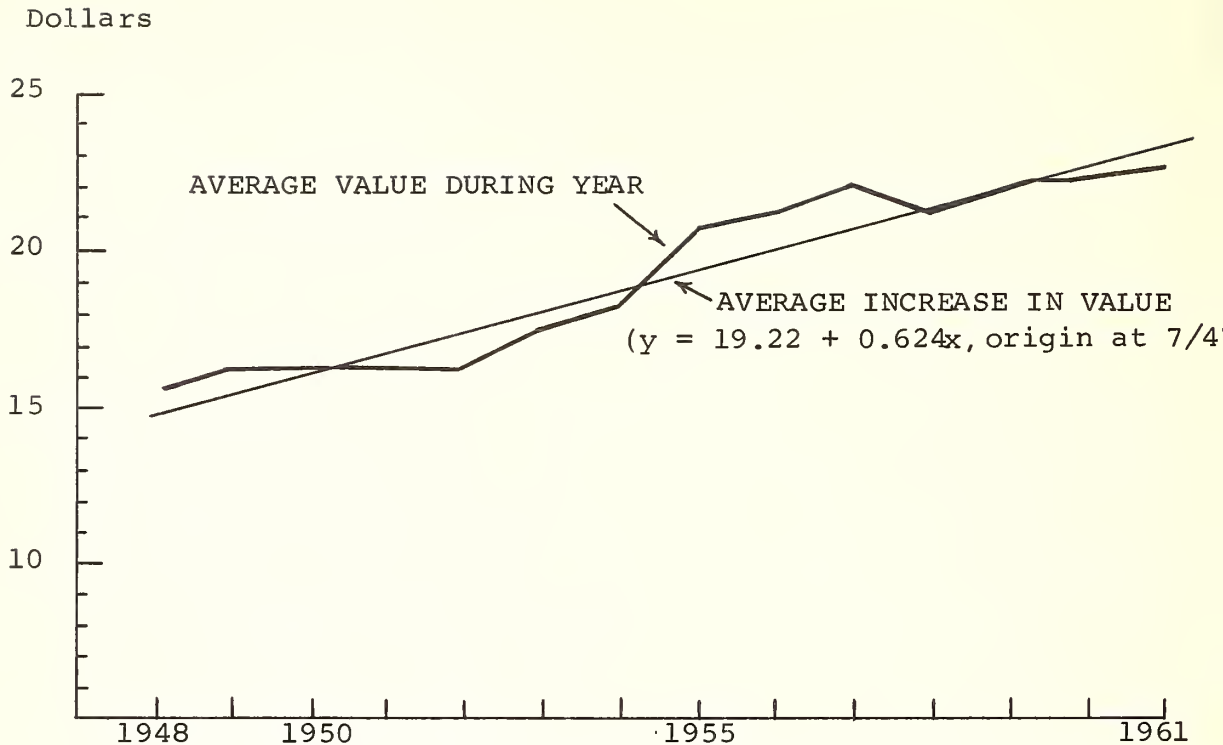


Figure 7-3. AVERAGE VALUE PER SHORT TON FOR FULLER'S EARTH, 1948-1961

Source: Minerals Yearbook, 1961

Fuller's earth products are distributed in several ways as illustrated in Figure 7-4. Bleaching clays are used at relatively few centers where oils are processed and are generally sold directly by the clay manufacturer to the refiner. On the other hand, absorbents are sold through various brokers, distributors, and jobbers or in some cases, directly to the larger users.

The marketing area for the major fuller's earth products is nationwide. However, 86 percent of the tonnage and 89 percent of the value of the 1961 production¹ is derived from the Florida-Georgia

¹Minerals Yearbook, 1961

are just north of Tallahassee. The one major producing area with many processors ships most of its products to the entire United States. Similarly, the scope of the Mississippi-Tennessee producers is nationwide. Slight differences in products and the fewer producers in the latter area tend to prevent the establishment of regional market patterns. It follows that at present, neither product application nor transportation cost determine the market area.

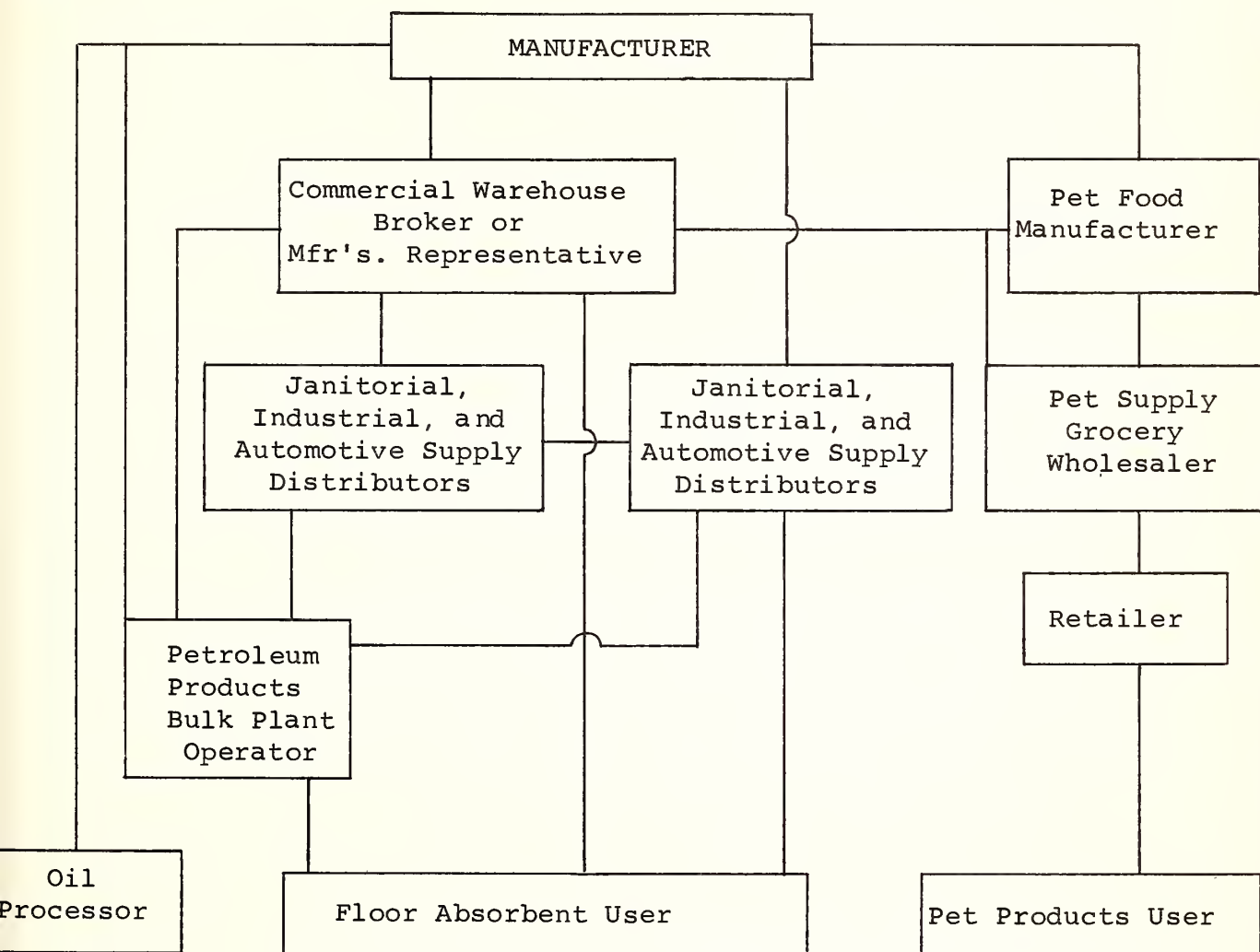


Figure 7-4. DISTRIBUTION TECHNIQUES USED BY MANUFACTURERS OF FULLER'S EARTH PRODUCTS

Fuller's earth markets are dominated by clay produced in southern Georgia and northern Florida where, in 1958, 10 of the 14 fuller's earth plants were located.¹ Attapulgite, as the Georgia-Florida clay is known, is superior in many applications to the montmorillonite-type fuller's earth clays. The bulk density of granular calcined attapulgite is very low (22-28 pounds per cubic foot) and absorption is very high. Both of these qualities are desirable in most commercial uses. Ninety different products are made from attapulgite by one large processor.² The versatility of this clay, the desirable characteristics of the products produced from this clay, and the acceptance through many years make competition formidable.

There exists in the clay trade a notion that the northernmost deposits of Porter's Creek located in Tennessee and Kentucky are inferior to the southern deposits of Porter's Creek equivalents in Mississippi. This has not, as far as is known, been demonstrated experimentally.

Montmorillonite-type fuller's earth products are presently being manufactured by the following five plants: Star Enterprise, Inc., Olmsted, Illinois; Southern Clay Company, Paris, Tennessee; Tennessee Absorbent Clay Co., Paris, Tennessee; (also owns a plant in Wrens, Georgia); Wyandotte Chemicals Corp., Blue Mountain, Mississippi; Oil-Dri Corporation of America, Ripley, Mississippi. (Oil-Dri also owns a plant in Cairo, Georgia.)

These plants account for less than 15 percent of all fuller's earth sold. All of these plants are processing the Porter's Creek formation, making only absorbent products. Analysis of production statistics from the Bureau of Census and the Bureau of Mines combined with field interpretation indicate the average output per plant of the two plants in Mississippi and the two plants in Tennessee to be 10,500 to 12,500 tons per year.

Bentonite has almost completely replaced fuller's earth as a bleaching agent for oils. The acid-activated bentonites dominate

¹Census of Mineral Industries, 1958. In 1964, five plants operate in Mississippi, Tennessee, and Illinois.

²Chapley, N.R. Attapulgite: 1 Process, 90+ grades. Chemical Engineering, V 68, No. 26, Dec 1961, pp 60-62

this market today, having captured at least 85 percent of the total bleaching clay market. Diatomaceous earth also is used extensively in oil bleaching.

Bleaching Clays

The most significant change in the consumption of fuller's earth since World War II has been a decrease in its use as an oil bleaching agent (Figure 7-1). This decline has been greatest in mineral-oil (petroleum products) processing, consumption falling from 200,000 tons in 1946 to 25,000 tons in 1960.¹ More efficient oil-processing techniques and increased use of the more economical acid-activated bentonites² resulted in the use of less natural bleaching clays. Although there has been an increase in the amount of oil processed, the more efficient processing techniques offset the need for additional bleaching clays.

The average price for bleaching-grade fuller's earth is \$17.50 per ton FOB plant.³ Oil processors use large quantities of bleaching clays (at least three percent raw clay is used by weight for most oils) and buy directly from clay processors. Vegetable oils are generally bought by manufacturers as crude oils and bleached or clarified before making the desired products (salad dressing, shortening oil, paint, soap, etc.). Mineral oils are bleached with clay during extraction.

Most bleaching in petroleum oil refining is done in the manufacture of lubricating oils where sludge, water, and carbon are removed. Oxidation properties, acidity, emulsion properties, and viscosity index are also improved by treating. Less bleaching clay is required for refining Pennsylvania-type crudes because they contain less asphaltum and other undesirable constituents. Technological improvements like the solvent extraction process in the production of lube oil have resulted in an increasingly cleaner and more

¹Rich, A.D., 1960, Bleaching Clay in Industrial Minerals and Rocks: pp 93-101, Ch 6, American Institute of Mining Metal and Petroleum Engineering, New York.

²That bleaching power of raw clay is 1/3 that of acid activated bentonite is a common rule of thumb in the oil processing trade.

³Minerals Yearbook, 1961

saleable product. Thus, the demand for clays by the oil refiners has declined considerably. Not all refineries are even potential customers since some do not produce lubricating oil.

Absorbent Uses

Fuller's earth used as an absorbent represents the largest and most rapidly increasing usage, amounting to nearly 45 percent of the fuller's earth production in 1961 (Figure 7-1). The three main absorbent products ranked by consumption are floor absorbent, animal litter, and soil conditioner. The upward trend in the use of fuller's earth as an absorbent may be leveling off¹ because consumption was essentially static (Figures 7-1 and 7-5) for absorbent products during the last three years for which figures are available (1959 to 1961)². Part of this leveling off may be due to machinery replacement in industry. Although the older equipment used in many factories depends on open lubrication, many newer machines scavenge lubrication oil for reuse or have sealed bearings that never need lubrication. Service stations and auto repair garages, although increasing in number, may not use as much floor absorbent per unit as before, because many service stations are now built without car lubrication facilities. Some garages and car service centers are so well maintained that nothing is tolerated on the floor, including floor absorbents. Soaps and detergents are used to remove dirt, grease and oil from the floor in these facilities.

Floor Absorbents. Wholesale prices for floor absorbents vary from \$17 - \$36 per ton FOB factory. Retail prices vary widely also. (See Table 7-1.) The difference in price depends on product differentiation the manufacturers have been able to establish, grades, and source of material. Attapulgit-type floor absorbent, for example, sells in all cases for at least \$3 per ton more than the montmorillonite type.

¹U. S. Bureau of Mines data for 1962 published after this was written indicate that the use of fuller's earth in absorbents is continuing the general upward trend.

²Recently published figures (Minerals Yearbook, 1962) show an increase to 206,978 tons for 1962.

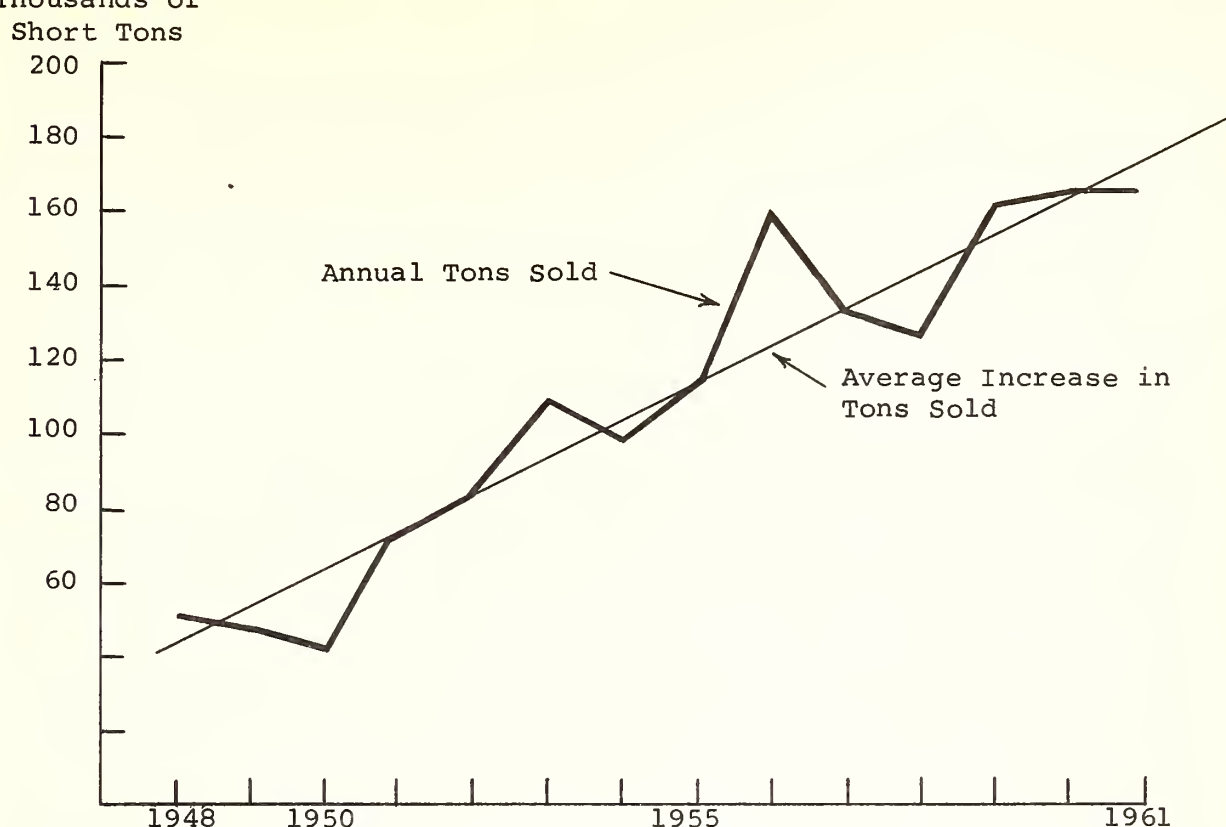


Figure 7-5 FULLER'S EARTH USED FOR ABSORBENT PRODUCTS, 1948-1961.

Source: Minerals Yearbook, 1961

Table 7-1

CONSUMER PRICES FOR FLOOR ABSORBENTS
DELIVERED IN 50-lb BAGS¹

Amount	Price Per Bag			Price per Ton
Number of Bags	High	Manufacturer's Suggested	Low	
1	\$3.50	\$3.00	\$1.97	
2-5		3.00		
6-9		2.75		
10-19		2.00		
20-39		2.00	1.75	
40-199		1.8125	1.475	\$72.50
200-399		1.7375	1.375	69.50
400 ²		1.6875	1.313	67.50

¹These prices were determined in detail in Louisville and checked for accuracy in other Midwestern cities.

²A price of \$46.50 per ton was obtained for 680 bags (17 tons) FOB Lexington, Kentucky from one distributor in Chicago (material was to be shipped direct from mine in Tennessee).

Grades of floor absorbents are determined by calcining temperature and by type of clay raw material used in manufacture. A floor absorbent calcined 1000-1200°F will perform well in absorbing oil, grease and water. Heating the same raw material to 600-800°F results in a product that breaks down much quicker in water and can be used only for grease and oil absorption. The floor absorbent made from attapulgitic clay is considered in the trade to be of a higher grade than the absorbent made from Porter's Creek Clay because of lower bulk density and higher absorption capacity. (See Section 5.)

Another factor affecting prices is promotional costs. These costs are paid by the manufacturer in the case of Mississippi and Florida-Georgia fuller's earth processors, and these expenditures are passed on to the distributors in the form of higher prices. The Tennessee manufacturers spend relatively little for promotion, leaving this task to brokers and distributors. This is another reason for their lower prices. The reseller of Mississippi and Florida-Georgia products gets sales help and literature from company representatives who often write orders for the reseller. Local warehousing of material for resellers who can not or will not buy in carload lots also is a service some manufacturers or their brokers offer to customers.

Floor absorbents are distributed directly by the manufacturer (particularly to big users), and also by distributors selling to smaller users (Figure 7-4). Commercial warehouses in larger cities and brokers selling to distributors also are important in the distribution network. Janitorial supply firms, as well as distributors selling other supplies such as solvents and lubricants, sell absorbents to industrial accounts. Service stations and auto repair garages generally buy fuller's earth from automotive supply wholesalers as well as petroleum bulk plants who distribute products to a chain of outlets, such as Standard Oil Company. Regardless of who is the final user, one or more of the following functions is performed in distributing absorbents: warehousing, delivery (often a bag or two at a time), credit extension (generally on a 30 day basis), and soliciting.

Although industrial users probably represent the largest market for absorbents, consumption figures are not available, nor can an average plant consumption be derived because of variation in sizes and types of plants. Most service stations use three to five 50-pound bags of floor absorbent per year depending on degree of

cleanliness and size of station.

Annual total floor absorbent consumption is approximately 135,000 tons in the United States, based on estimates using data from Minerals Yearbook.

Animal Litter. Animal litter, especially cat litter, represents a growing usage for absorbent clay. If only one third of the eleven million families owning cats¹ bought a 10 pound bag per month, the potential consumption would be 220,000 tons per year or about half of the total present yearly consumption of fuller's earth for all uses.

Many processors of fuller's earth now make or can make cat litter, the chief requirement being equipment suitable for bagging small quantities of material. Processors sell to pet supply wholesalers, brokers, pet supply manufacturers, and grocery jobbers throughout the United States. Due to this myriad of resellers, little meaningful information can be collected on the extent of the market, although it is substantial and growing, amounting to an estimated 40,000 tons per year. The producers are generally secretive about sales breakdown and production.

The price to the distributor for cat litter is higher than for floor absorbents, because of the extra production costs for smaller bags and more handling, plus greater promotional costs. (\$45-50 per ton FOB plant is a common price charged distributors in 50 pound bags). A retail price schedule is shown in Table 7-2. The supermarkets have greatly affected the retail price since their entry into the cat litter market.

Chain grocery warehouses or their suppliers and pet supply manufacturers and wholesalers are good potential customers for cat litter. Large suppliers of pet foods and/or products like Ralston-Purina and Hartz Mountain are possible customers although they buy from established plants at the present time. Cat litter complements a pet food line, making more profit for retail and wholesale customers because of fewer supply sources and less handling. Realizing this, manufacturers are attempting more and

¹Pet Food Institute 6th Annual Convention "Highlights" September 15-17, 1963.

more to sell to pet food manufacturers. A representative from a large supermarket chain said his company was interested in a low-priced and highly-advertised cat-litter product.

Table 7-2

CONSUMER PRICES FOR ANIMAL LITTER *

Package Size	Retail Price			Dealer		Distribution FOB Plant
	Chain Store	Common	Suggested	Largest	Smallest	
4 lb.	.29					
5 lb.	.39	.45	.59	.25	.31	.16
10 lb.	.49	.89	1.15	.47	.59	.30
25 lb.		2.25	2.75	1.10	1.42	.70
50 lb.		3.95	4.50	1.90	2.50	1.20

*Prices are based on detailed analysis in the Louisville area and are typical for the Midwest as determined by spot interviews in other areas. Prices are quoted in dollars and cents.

Soil Conditioner

The market for calcined fuller's earth as a soil conditioner has not been fully developed. Presently, golf courses are using the material on greens to improve the water-holding capacity of the soil and represent the largest market. The material is also now being used on a very limited basis in greenhouse benches, cold frames, hot beds, etc. The turf market potential is large if favorable results continue to be reported. The number of golf courses is increasing¹ and turf specialists are willing to experiment. Low water breakdown is very important in this application since the beneficial characteristics of the material are lost if it slakes down rapidly. Calcined Porter's Creek Clay is particularly good in resistance to water breakdown, making the use of this product highly desirable in soil conditioner applications.

¹According to the Wall Street Journal, Oct. 15, 1963, there are 7,600 golf courses in the United States today, and about 700 new ones are constructed each year in the United States.

FOB prices are around \$60-per ton to golf courses; distributors pay \$32-35. The recommended rate of application is 200 pounds of calcined clay per thousand square feet, applied with an aerifier machine. This may be doubled or tripled depending on soil type, etc. Application rates have not been fully determined since much work is still in the experimental and development state.

The clay is also used on cemeteries, schools and stadium turf. The football field at Purdue University, for example, has 100 tons of calcined clay fuller's earth worked into the soil.

It is estimated that less than 12,000 tons a year are sold in the United States for soil conditioner. Distribution is by brokers and distributors to consumers. Direct sales are not important in this application, since golf courses are usually supplied by local or regional distributors who offer many services including application and consulting services. These distributors are well established, making sales through them more beneficial, at least at present.

Other Fuller's Earth Products

Twenty-five percent of all fuller's earth sold is used as a pesticide carrier for insecticides, fungicides, and herbicides. However, all of the fuller's earth used as carrier is of the attapulgite type because of technical reasons discussed in Section 6. Demand has fluctuated between 58,000 tons and 100,000 tons since 1953. Figures on amount of fuller's earth used in pesticides are not available prior to 1953. Markets for attapulgite used as a carrier generally have increased, but consumption severely declines periodically (e.g., the 1957 usage was almost half that for 1956), because infestation by insects and diseases varies greatly with weather factors. Other pesticide carriers such as talc, kaolin, bentonite, and pyrophyllite compete with fuller's earth. Insecticide formulators use both dust and granular carriers, and any formulator would be a potential customer. However, the entrenchment of attapulgite producers in this market makes the prospect for developing sales of Porter's Creek Clay doubtful.

Other uses for fuller's earth are drilling muds, water purification, and fillers for soaps. Fuller's earth is also used in varying amounts in some plastics, polishes, and greases. Attapulgite fuller's earth is used for these applications because

of its lower bulk density, or other desirable property such as color, and because it has been more effectively promoted.

OUTLOOK FOR CLAY PRODUCTS FROM MARSHALL COUNTY

Comparative Advantages

Fuller's earth products from Marshall County would have several advantages over competitors.

Freight. Any plant in Western Kentucky has a freight advantage over 11 of the 13 fuller's earth processing plants for sales in the industrial Midwest. Some freight rates are:

<u>To</u>	<u>From: Ga. Plants</u>	<u>Miss. Plants</u>	<u>Ky. & Tenn. Plants</u>
Chicago	\$14.10/ton	\$10.56/ton	\$ 9.56/ton
Cincinnati	12.25	9.38	7.93
Louisville	11.64	8.56	7.06
St. Louis	12.46	7.98	4.85

Physical Properties. The Porter's Creek Clay found in Mississippi, Tennessee and Kentucky resists breakdown in water better than the clays found in the Florida-Georgia area. This resistance to "mudding up" is advantageous, especially for soil conditioner and floor absorbent uses. The reddish-pink color could be an advantage, especially for cat litter, if it were promoted as being aesthetically more appealing (to cat owners). The attapulgite clay is much lighter in color (almost white) than Porter's Creek when calcined.

New Productive Capacity. The processing plant proposed for Marshall County, if operated at capacity, should be more efficient in terms of unit cost than the typical plant now in operation. Much of the plant would be automated, reducing labor costs. Also, since raw material for this plant will be adjacent to the plant, it will be possible to have very low clay acquisition costs.

Comparative Disadvantages

The high bulk density of Porter's Creek Clay is a disadvantage in most product applications. The lower absorption properties

(see Section 5) especially for the granular material, is a disadvantage also. The entrenchment in many markets with most existing customers by the present producers will be a disadvantage to any new plant.

Competitors' Marketing Activities

Present producers of fuller's earth, especially the Georgia, Florida and Mississippi operators, offer many services to their customers. They have salesmen calling on large accounts on a regular basis and helping with selling problems. The company representative often accompanies distributor salesmen on sales calls to improve their sales techniques and knowledge about the products. The distributor expects to receive some orders for absorbents from the manufacturer's salesmen. One manufacturer stocks 80 commercial warehouses with his products for customer use.

Specific Product Evaluations

The chief factors that were considered in evaluating the specific uses for the Marshall County clay deposit include adaptability of raw material to making the various products, market sizes locations, and prices and price trends.

Bleaching Clay. Porter's Creek Clay, although formerly used extensively for bleaching purposes, no longer meets the requirements for most uses in the mineral-oil, vegetable-oil, or animal-oil industries. It has been replaced by materials such as acid-activated bentonite which are more efficient because of lower oil retention. Although a few oil processors may continue to use natural fuller's earth for bleaching oils, this use can be considered minor and unlikely to expand. It is particularly hard to break into the bleaching clay market because the bleaching trade is supplied on a past-performance basis. A supplier must prove the value of his product in the customer's plant before orders can be obtained. Therefore, considerable sales promotion would be required to develop this use.

Because of the declining market for natural bleaching clays and the unlikely prospect for any improvement, very little if any clay from the Porter's Creek could be sold to oil processors.

Floor Absorbent. It will be possible to manufacture a salable floor absorbent from the Porter's Creek Clay in Marshall County. As covered in Section 6, this product will not meet federal specifications, but tests show it will at least equal in quality the floor absorbent currently being produced from the Porter's Creek Clay by the four plants in Tennessee and Mississippi.

The locational advantages offered by Marshall County mean lower freight rates to central and north-central markets in the United States over plants in Georgia, Florida, and Mississippi. There is no freight advantage, however, over the two existing plants in Tennessee.

The market for floor absorbents includes the entire United States; however, due to the concentration of population and industry the prime market area for floor absorbents manufactured in Western Kentucky would be the north-central and eastern states. In this area, approximately 110,000 tons of floor absorbent are consumed yearly, and there is an indication that this is a growing market. This is not to say business should not be solicited in the rest of the country, but rather that the first efforts should be concentrated in this heavy-consuming area.

Prices are relatively stable at the present time. The attapulgitite-type floor absorbent sells to distributors for a higher price than the montmorillonite type. The former sells in the mid-thirty dollar range per ton; the latter in the low thirties. Some manufacturers, however, sell to large distributors at less than \$20 per ton, thereby competing with their own brokers and smaller distributors.

The Marshall County plant, given effective salesmen, several key accounts, and some large distributors or brokers could capture 7 percent of the United States market in the first year of operation; 10 percent by the second year, with 14 percent by the fifth year. To attain these market penetrations, which are relatively high percentages of the total market, it is estimated that a major portion of the product will have to be sold through brokers at relatively low cost. Otherwise, such high market penetrations probably could not be obtained. However, more than half the sales will have to be made through company salesmen acting through distributors (representing penetrations of 4 percent, 6 percent, and 8 percent in the first, second, and fifth

years of operation, respectively). The Marshall County operators should be able to sell amounts at average wholesale prices as follows:¹

<u>Floor Absorbent</u>	<u>Sold Through Distributors Direct to Users</u>	<u>Sold Through Brokers</u>	<u>Total Tons</u>
1st Year	5,500 tons @ \$20.00/ton ²	4,000 \$18.00	9,500
2nd Year	8,100 tons @ \$20.00/ton	6,000 \$18.00	14,100
5th Year	10,800 tons @ \$20.00/ton	8,000 \$18.00	18,800

Animal Litter. A satisfactory, salable animal litter product can be easily made from Porter's Creek Clay.

Plant location would have little bearing on sales since promotion and timing are the only practical differences between the present manufacturers who are succeeding with their litter line and those who are not. The market potential is large and will not be satisfied for several years even though the cat population is declining slightly.³ The picture is bright, but much energy and many ideas would be necessary to get established in this market.

It would be difficult, but not impossible, to get 5 percent of the estimated national litter market. If achieved it would result in sales of 2,000 tons per year. However, the present production cost for this amount would be excessive and would not justify investment in production equipment and additional labor. When the

¹ See Table 7-1 for range in consumer prices for floor absorbents in a typical market area, Louisville. Consumer prices range from slightly under \$70 to about \$80 per ton. Transportation, warehousing, handling, and distributors costs account for up to three-fourths of the price to the consumer.

² The wholesale price for absorbents (including attapulgitic types) varies from \$17-36 per ton as discussed on page 7-8. The average price for a Marshall County plant is estimated at \$20 mainly on the basis of quality of the product and price level necessary to attain the desired market penetration.

³ Pet Food Institute, op. cit.

floor absorbent line is profitably established and a considerable effort can be given to litter development, the situation should then be reviewed.

Soil Conditioner. Because of nearness to the north-central markets and good qualities of Marshall County fuller's earth for making soil conditioners, this use will be an important but small sales item. However, the market will have to expand before much can be profitably accomplished. Emphasis should be placed on this market after floor absorbent sales are well established. Soil conditioner could materialize in the next three to five years into a large market for fuller's earth. Currently, the total market is estimated at about 10,000 to 12,000 tons per year. With a concentrated effort, 500 tons should be sold in the first year of operation at \$30 per ton FOB plant. The second and fifth year sales are conservatively estimated at 600 and 900 tons, respectively, at the same price.

Pesticide Carriers. There is little likelihood that Porter's Creek Clay will ever become an acceptable carrier for pesticides due to its high bulk density and dark color. (See Section 6.)

Specific Market Area Evaluations

To estimate the local demand in cities in the vicinity of the proposed plant, particular attention was given to the population, degree of industrialization, and modes of distribution of products for each area. The intricacies of marketing products with the most promising national demand were studied in detail in Louisville, Lexington, and Indianapolis. Virtually every company and individual selling fuller's earth products was interviewed in these three cities to establish the marketing pattern. Spot interviews with sellers located in Cincinnati, Chicago, Evansville, Columbus and St. Louis were used to verify that marketing patterns were similar in regional and local marketing areas. Salesmen covering the northeastern and north-central United States were also interviewed; the sales estimates, prices, and marketing conclusions were read to one independent salesman who confirmed that the findings were realistic.

The market area with the most potential is the northeastern and north-central states. Due to competition and lower demand, the southeastern United States offers the poorest market potential.

Average per capita consumption for fuller's earth floor absorbents is 1.5 pound based on the 1960 census and 1961 Bureau of Mines production statistics (Table 7-3). However, the north-central states, where an estimated 55,000 tons of absorbents are sold, yield an average per capita consumption of slightly over 2.0 pounds. The estimate of tons sold in the north-central states is based on results of interviews with distributors and manufacturers combined with population and production statistics, and degree of industrialization. The estimates are rough approximations because distributors and manufacturers almost invariably withheld the exact amount of absorbent sold in each area to protect their competitive positions.

Adjustments from average local and regional per capita consumption were made to reflect the prevailing market factors. For example, St. Louis is less than three times larger than Louisville, but it is estimated that more than three-and-a-half times as much absorbent is sold in the former because of proportionately more heavy industry and a larger service area in St. Louis and vicinity. On the other hand, Louisville and Indianapolis, it is estimated, have roughly comparable demand and size.

Table 7-3 summarizes the estimated demand in four regions and eight cities. Other cities such as New York, Boston, Cleveland, Milwaukee and Akron are large consumers and should also eventually be served by the proposed plant.

Table 7-3

SUMMARY OF QUANTITATIVE MARKET ANALYSIS FOR FLOOR ABSORBENTS

Area	Estimated Tons Annual Consumption	Population ¹	Estimated Pounds of Absorbents Sold Per Capita	Percent Industriali- zation	Number of ³ Mfg. Plants
United States	135,000 ⁴	179,323,175	1.5	9.77	298,453
N.E. States	55,000	44,677,819	2.4	12.8	106,184
N.Central States	55,000	51,619,139	2.1	11.0	80,932
South	15,000	54,973,113	0.6	7.24	65,120
West	10,000	28,053,104	0.7	7.56	46,244
Cincinnati ⁵	1,200	1,071,624	2.2	12.3	1,776
St. Louis ⁵	2,500	2,060,103	2.4	12.2	3,151
Louisville ⁵	700	725,139	2.0	11.0	873
Columbus ⁵	700	682,962	2.0	9.84	836
Evansville ⁵	180	199,313	1.8	10.7	272
Chicago ⁵	8,000	6,220,913	2.6	13.8	13,508
Lexington ⁵	80	131,906	1.2	5.72	127
Indianapolis ⁵	750	697,567	2.1	12.5	1,101

¹County and City Data Book, 1962, U. S., Bureau of the Census.²Percent of population employed in durable and non-durable manufacturing industries op. cit.³Estimated for 1958, in County and City Data Book, 1962.⁴Minerals Yearbook indicates that about 185,000 tons of fuller's earth were sold as absorbents in 1961. However, about 50,000 tons were used as animal litter and soil conditioner.⁵Standard Metropolitan Area.

Section 8

CAPITAL REQUIREMENT AND PRODUCTION COSTS

EQUIPMENT SELECTION

The standard method used in the manufacture of granular fuller's earth products consists of calcining fragments of clay in a rotary kiln to temperatures between 600° and 1200° F and using a roll crusher and classifier to make a granular product. The lower temperatures are used to make lower quality products. Temperatures between 1000° and 1200° are required to make low density, highly resistant particles with a marketable color. The temperature at which the montmorillonite structure breaks down (approximately 1000° F) should be exceeded in order to make low density and highly resistant granules. The higher temperatures also allow complete burning off of organic matter, yielding a uniform and acceptable color. The oil absorption for some samples is considerably enhanced by heat treatment to 1200° F. (See Section 5.) Plants manufacturing fuller's earth products at the lower temperatures are operating at about one-half or less of capacity, and consumers favor the higher-quality products. Thus calcining above 1000° F appears to be essential to the marketing of sufficient fuller's earth to justify a plant.

A flow chart and a schematic diagram illustrating the process stages for a mechanized plant are shown in Figures 8-1 and 8-2. The estimated capital requirement for a turnkey plant utilizing a gas-fired (oil stand-by) rotary kiln capable of attaining temperatures of 1200° F is shown in Table 8-1.

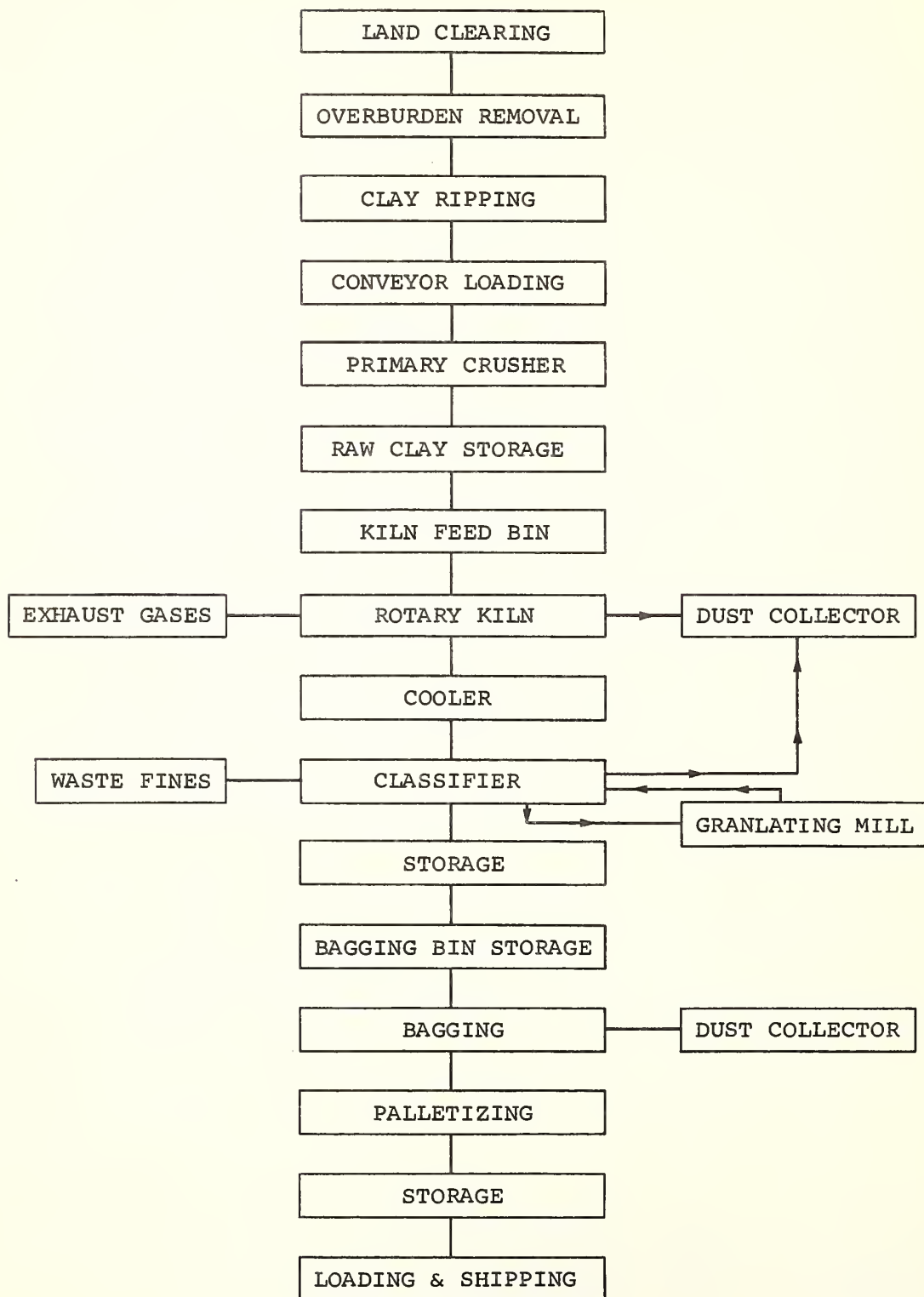
Table 8-1

ESTIMATED CAPITAL INVESTMENT

Land 9 acres @ \$300/acre	\$ 2,700
Turnkey plant 60 TPD (provision for 75 TPD, building and all equipment)	370,000 ¹
Site clearing and preparation	<u>30,930</u>
	\$403,630

¹Cost based on Allis-Chalmers Manufacturing Company's estimate for 80 TPD plant.

Figure 8-1 PRODUCTION FLOW CHART



The estimate includes all mining and production equipment,¹ buildings,² loading and packaging facilities,³ utilities hook-up,⁴ and dock-site work. Start-up supervision and guaranteed performance are also included. The estimate is intended to represent minimum costs for a plant (not including working capital) that will compete with other fuller's earth producers. However, the possibility exists that competitive bidding or selecting lower-cost items of equipment might reduce the capital requirement for an automated plant.

The Area Redevelopment Administration requested that a labor-intensive plant having a lower capital requirement be compared with the automated plant. Table 8-9 at the end of this section and Table 9-2 show estimated differences in plant operating costs and profitability

¹Mining equipment: tractor-loader with ripper attachment, portable belt conveyor and feeder. Process equipment: primary crusher, raw-storage bin, kiln-feed bin, refractory-lined rotary kiln, dust collector and kiln exhaust system, Warner-type cooler, burners, kiln control system, screen classifiers, granulating mill, waste-disposal system, bulk-product storage bin, and belt conveyors and feeders.

²Approximately 20,000 square feet of floor space for processing, bagging and palletizing, and warehousing (three separate rooms and partially open, covered area). Specifications for buildings designed for low insurance rates. Office building with small quality-control testing facilities, approximately 450 square feet in size.

³Bagging units for vent-type bags complete with exhaust system, conveyor to palletizing area, and fork-lift truck.

⁴Three-phase electrical service supplied to site by West Kentucky Rural Electric Cooperative Corporation.

Four-inch gas line provided by Western Kentucky Gas Company on negotiated basis (see discussion later in this section).

Water supplied from intermediate-depth well at site with estimated potential of 50 to 200 gpm (cost of well included under site preparation, Table 8-1).

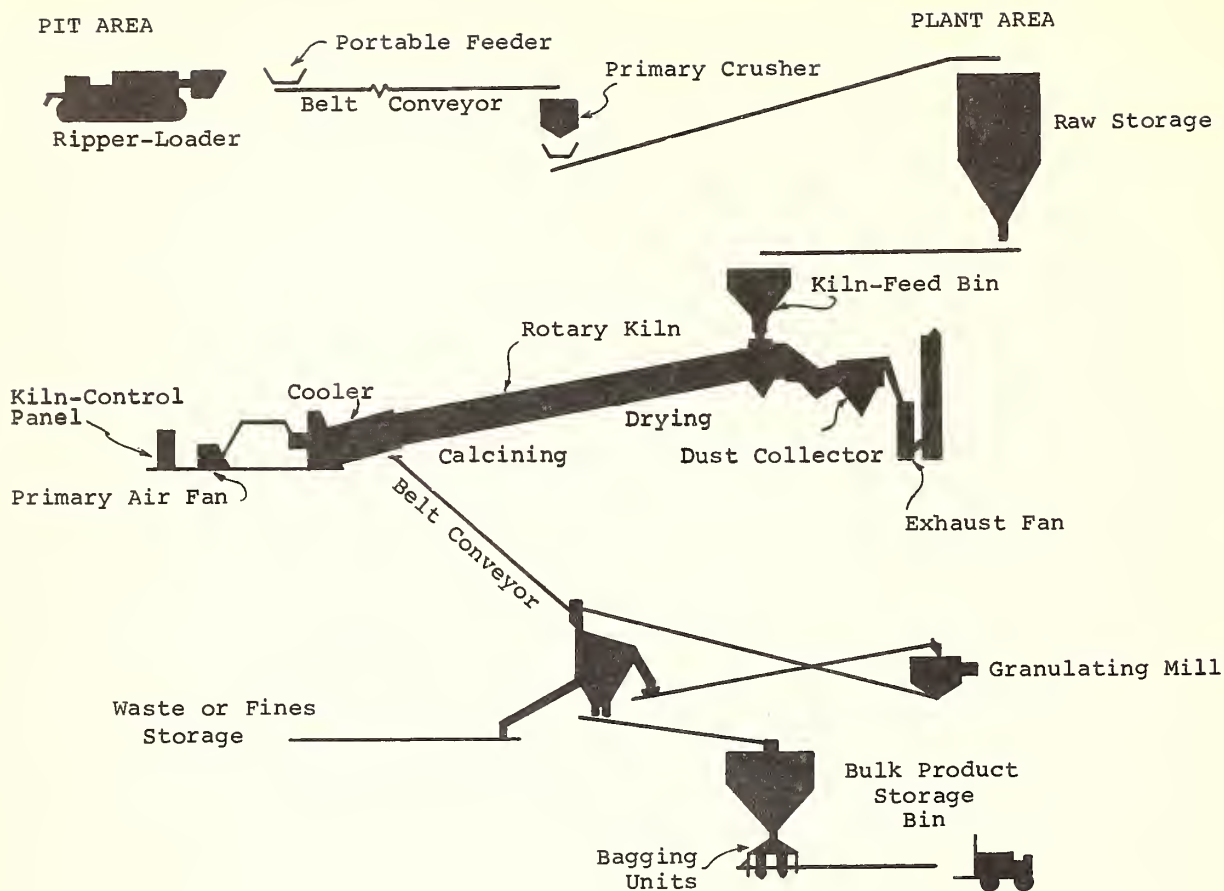


Figure 8-2. Schematic Diagram - Fuller's Earth Plant

for capital-intensive and labor-intensive plants. The latter was found to be not economically feasible. The main reason for the differences in profitability is that the decrease in depreciation and interest charges is more than offset by increases in labor costs in the labor-intensive plant. If all plants were labor intensive and a higher price prevailed for fuller's earth products, it might be possible to operate a labor-intensive plant profitably until automated facilities began to compete. This is not the case, however.

The project team was also asked to evaluate the feasibility of utilizing a gas-fired, infrared kiln having a lower capital requirement than the conventional rotary kiln. An infrared kiln of the type currently being used to dry silica sand could hypothetically handle 60 TPD with considerably shorter contact

period per unit weight, and with smaller and lighter equipment. Savings in refractory lining replacement might also be effected because only the bottom of the infrared oven is in contact with the process materials, which move in sawtooth fashion over the gyrating base. The amount of energy required to dry silica sand is approximately the same as with rotary equipment and no difference in this item of cost can be anticipated. However, since the infrared oven utilizes a radiation method, less difficulty is encountered in start-up or shut-down, yielding greater flexibility of firing schedules.

Column 3 in Table 8-9 shows the preliminary (pre pilot testing) estimated capital requirement and production costs for a plant utilizing an infrared kiln. The applicability of this method would have to be demonstrated in pilot tests before it can be technically justified, however. There is no assurance that the infrared method using short contact period will completely calcine the granular product. One may argue that the time might not be sufficient to calcine each granule to the center, resulting in an inferior product. Thus, pilot testing is required before further evaluation can be made. Estimated production cost and capital requirement may require considerable adjustment after pilot tests are made. The hypothetical costs are included merely to show the possible savings that may result from using this new innovation. The development of a new pyro-processing technique will probably more than offset the savings in capital requirement; therefore the primary consideration on selection of calcining equipment should be based on operating costs and overall profitability.

Because of the uncertainties associated with a plant utilizing infrared equipment, and the fact that a labor-intensive plant would not be feasible, the following detailed information is developed only for an automated rotary-kiln plant.

SCALE FACTORS

The minimum plant size for a rotary kiln operation based on analysis of calcining schedule, labor requirements, and materials handling is estimated at about 50 tons per day. This results from the necessity for keeping calcining equipment in continuous operation for long periods if efficiency is to be maintained. For production less than 50 tons per day, there would be a sharp rise in per unit labor cost, and a difficulty in scaling down the equipment to this low rate.

The optimum size of plant is based on a consideration of economies of scale and size of market. It is estimated that a plant capable of producing 60 tons per day should be optimum for serving the market for absorbents.

The plant will have to operate forty-eight weeks annually on a twenty-four hour basis to produce 20,000 tons of product. To produce 10,000 tons, only two weeks operation each month will be necessary because two continuous weeks per month is more desirable for avoiding inventory problems and shutting down the kiln.

Production inputs for a plant utilizing a rotary kiln are described and their costs for the 60 TPD plant are derived for each input (labor, power, etc.), in the following sections.

PRODUCTION COSTS

Labor

Tables 8-2 and 8-3 list labor requirements for 10,000 and 20,000 tons per year production, respectively. Qualifications and duties for each job category are given below.

Table 8-2

FIRST YEAR LABOR REQUIREMENTS

Classification	8 Hr Days/Yr/Man	Day Shift	2nd Shift	3rd Shift
Plant Foreman	260	1		
Operator	180	1	1	1
Mining Man	250	1		
Utility Man	168	1	1	1
Maintenance Man	260	<u>1</u>	<u>1</u>	<u>1</u>
		5	2	2

Foreman

Experienced pyro-processing specialist with management ability and inventory management experience. Must be proficient in automatic processing techniques and be responsible for storage, packaging and shipment of final product.

Table 8-3

FIFTH YEAR LABOR REQUIREMENTS

Classification	8 Hr Days/Yr/Man	Day Shift	2nd Shift	3rd Shift	Extra
Plant Foreman	260	1			
Operators	252	1	1	1	1
Mining Man	260	1			
Utility Man	255	4	1	1	
Maintenance Man	260	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>
		8	2	2	1

Operators

Operates, adjusts, and supervises routine operations of processing equipment. This includes crushers, classifiers, baggers, kilns and conveyors.

Mining Man

Experienced heavy equipment operator. Responsible for complete mining operation from pit to plant. Works in plant as utility man or operator during bad weather.

Utility Man

Unskilled man to assist operator and maintenance man. Clean up, bag, stock, load and inventory final product.

Maintenance Man

Performs preventative maintenance; adjusts, repairs, lubricates mining and processing equipment. Responsible for handling maintenance and performs operator's function when necessary.

Table 8-4 shows the approximate number of available workers in Marshall County, and wages expected for specific jobs. The wage rates are those paid for similar or related work in this area. These rates vary in accordance with the amount of responsibility and type of industry involved.

Table 8-4

LABOR AVAILABILITY AND WAGE RATES

Occupation	Approx. Number Workers Available ¹	Approx. Wage Expected ¹
Plant Foreman	6	\$400 to \$500 per month
Operator	100	\$1.75 to \$2.00 per hour ²
Mining Man	75	\$2.25 to \$2.50 per hour
Utility Man	225	\$1.50 to \$1.75 per hour
Maintenance Man	200	\$2.00 to \$2.25 per hour

¹Estimates made by Department of Economic Security, Paducah, Kentucky, December, 1963.

²Estimated at \$2.50 per hour in Tables 8-7 and 8-9 because of supervisory duties.

Power

Natural Gas. The Western Kentucky Gas Company will run an adequate supply line from a point in the Texas Gas Transmission high-pressure line to the proposed plant. The payment for this line can be negotiated at the time of plant construction. Because costs are recovered,¹ no provision for pipeline construction cost is included in profitability analysis.

The estimated natural gas requirements were calculated for both the 10,000 tons-per-year and the 20,000 tons-per-year plants. The former will use 1,000,800 cubic feet per month; the latter 2,001,600. The fuel cost (Table 8-5) was based on an uninterruptible rate schedule supplied by Western Kentucky Gas Company.

¹The manufacturer "pays for the entire cost of the extensions less an amount equal to ten percent of his estimated initial annual gas cost". The gas company refunds to the customer "an amount equal to ten percent of his annual cost of gas each year for a period not exceeding ten consecutive years from the date gas is first utilized, or until the entire payment or deposit, without interest, has been refunded, whichever occurs first". Quotes from letter dated January 2, 1964 from Western Kentucky Gas Company.

Table 8-5

NATURAL GAS COST

10,000 TPY Production using 1,000,800 cubic feet/month:

1,000 cu ft	\$ 1.50
2,000 cu ft @ 0.0895 per 100 cu ft	1.79
7,000 cu ft @ 0.0725 per 100 cu ft	5.08
40,000 cu ft @ 0.0665 per 100 cu ft	26.60
950,800 cu ft @ 0.0595 per 100 cu ft	<u>565.73</u>
Monthly Cost	\$ 600.70
12-Months Basis	\$7,208.40

20,000 TPY Production using 2,001,600 cubic feet/month:

1,000 cu ft	\$ 1.50
2,000 cu ft @ 0.0895 per 100 cu ft	1.79
7,000 cu ft @ 0.0725 per 100 cu ft	5.08
40,000 cu ft @ 0.0665 per 100 cu ft	26.60
1,951,600 cu ft @ 0.0595 per 100 cu ft	<u>1,168.77</u>
Monthly Cost	\$1,203.74
12-Months Basis	\$14,444.88

Electricity. Western Kentucky RECC will supply electrical service to the proposed plant. Power requirements for the plant are based on information supplied by Allis-Chalmers Manufacturing Company. Electricity costs are shown in Table 8-6 for 10,000 and 20,000 tons annual production.

Other Production Costs. (See Tables 8-7 and 8-8.) Payroll taxes and benefits were estimated at twenty percent of base pay for all employees.

Insurance on buildings and equipment was calculated at \$2.00 per \$100 value. This is somewhat high because the plant would be more than eight miles from a fire station.

Property taxes were calculated at \$2.40 per \$100 applied to one-third of the assessed valuation. Rate was obtained from the Marshall County tax office.

Straight-line depreciation was estimated at 6.7 percent on a 15-year schedule on the basis of U. S. Treasury Department's Publication No. 456 (7-62).

Table 8-6

ELECTRICITY COSTS¹

10,000 TPY Production using 50,400 KWH/month:		
100 @ 0.03	\$	3.00
400 @ 0.02		8.00
1,000 @ 0.01		10.00
1,500 @ 0.008		12.00
12,000 @ 0.011		132.00
25,000 @ 0.006		150.00
10,400 @ 0.004		<u>41.60</u>
		356.60
	Demand	<u>100.00</u>
		456.60
	Tax 3%	<u>13.70</u>
Total monthly cost	\$	470.30
12-months basis		\$5,644.00

20,000 TPY Production using 100,800 KWH/month:		
100 @ 0.03	\$	3.00
400 @ 0.02		8.00
1,000 @ 0.01		10.00
1,500 @ 0.008		12.00
12,000 @ 0.011		132.00
25,000 @ 0.006		150.00
60,800 @ 0.004		<u>243.20</u>
		558.20
	Demand	<u>100.00</u>
		658.20
	Tax 3%	<u>19.74</u>
Total monthly cost		677.94
12-months basis		\$8,135.00

¹Based on information supplied by Allis-Chalmers Mfg. Co. (electrical requirements) and West Kentucky RECC (rates).

Table 8-7

PRODUCTION COSTS

60 TPD PLANT

<u>FIXED COSTS</u>		
General Manager (1/2 Production, 1/2 Sales)		\$ 4,000
Plant Foreman		6,000
Clerical		2,340
Payroll taxes and benefits		2,468
Building and equipment maintenance		2,500
Insurance		7,400
Property taxes		2,962
Depreciation		24,790
Land rent		36
Interest on borrowed fixed & working capital		<u>19,440</u>
Total fixed costs		\$71,936

<u>VARIABLE COSTS</u>	<u>10,000 TPY</u>	<u>20,000 TPY</u>
Labor		
Mining	\$ 5,200	\$ 5,200
Operators	10,800	20,160
Maintenance	4,680	4,680
Utility men	7,056	21,392
Payroll taxes and benefits	<u>5,547</u>	<u>10,286</u>
Total labor cost	33,283	61,718
Power		
Electricity	5,644	8,135
Gas	7,208	14,445
Supplies		
Bags	28,000	56,000
Fuel, oil and grease	7,000	13,000
Pallets	7,500	15,000
Other		
Royalties	1,000	2,000
Miscellaneous	<u>4,482</u>	<u>8,515</u>
Total variable cost	\$94,117	\$178,813

Table 8-8

SALES COST

General Manager (1/2 Sales, 1/2 Production)	\$ 4,000
Salesmen (two)	20,000
Payroll taxes and benefits	4,800
General sales expense	3,000
Travel and subsistence expense	<u>20,000</u>
Total sales cost	\$51,800

Land rent of 50 cents per acre per year was obtained from the lease between Mr. Brummitte and the principals.

Interest on borrowed money was estimated at four percent on an ARA loan of \$262,360, six percent on a loan from a local development corporation (\$40,400), and an average of 5½ percent on loans from the Kentucky Industrial Development Finance Authority (KIDFA) and banks (\$80,670). Ninety-five percent of \$403,630 represents the maximum amount which an applicant can borrow from ARA and other sources. It was further assumed that working capital would be borrowed at a rate of six percent. Borrowed working capital was estimated at \$40,000 in the first year, \$30,000 in the second, and \$10,000 in the fifth year. To derive interest costs for the first and fifth years (Table 8-9), monthly repayment was assumed for the ARA loan and annual payments for other loans.

St. Regis Paper Company quoted bag prices at seven cents each. Fuel, oil and grease (including service costs) for the mining and processing equipment were estimated by the project team. Pallets were estimated at a cost of \$1.50 each. One-half the production was considered palletized for easier and more economical handling for both the manufacturer and the distributor.

Royalties were calculated at ten cents per ton as set forth in the lease with Mr. Brummitte. Miscellaneous costs of five percent were used to cover any unforeseen production cost.

The general manager and the salesmen salaries were estimated at \$8,000 and \$10,000 per year, respectively.

Table 8-9

COMPARISON OF ALTERNATIVE PLANTS

ESTIMATED CAPITAL REQUIREMENT			
	Capital Intensive Plant ¹	Labor-Intensive Plant ²	Capital-Intensive Plant (Infrared Oven) ³
Land - 9 acres @ \$300/acre	\$ 2,700	\$ 2,700	\$ 2,700
Plant & equipment - 60 TPD	370,000	257,000	335,000
Site clearing & preparation	<u>30,930</u>	<u>20,300</u>	<u>30,930</u>
Total	\$403,630	\$280,000	\$368,630 ⁴

ESTIMATED OPERATING COSTS						
	FIRST YEAR (10,000 TPY)			FIFTH YEAR (20,000 TPY) ⁷		
	Capital Intensive Plant ¹	Labor-Intensive Plant ²	Capital-Intensive Plant (Infrared Oven) ³	Capital Intensive Plant ¹	Labor-Intensive Plant ²	Capital-Intensive Plant (Infrared Oven) ³
Fixed costs						
General manager 1/2 time	\$ 4,000	\$ 4,000	\$ 4,000	\$ 4,200	\$ 4,200	\$ 4,200
Plant foreman	6,000	6,000	6,000	6,300	6,300	6,300
Clerical	2,340	2,340	2,340	2,440	2,440	2,440
Payroll taxes and benefits	2,468	2,468	2,468	2,468	2,468	2,468
Building & equipment maintenance	2,500	3,100	2,100	2,500	2,500	2,500
Insurance	7,400	7,500	7,200	7,400	7,400	7,400
Property taxes	2,962	2,400	2,830	2,962	2,962	2,962
Depreciation (straight-line)	24,790	17,350	21,970	24,790	17,350	21,970
Land rent	36	36	36	36	36	36
Interest on borrowed fixed and working capital	19,440	14,450	18,950	14,578	13,250	14,150
Total fixed costs	\$ 71,936	\$ 59,644	\$ 67,894	\$ 67,674	\$ 57,706	\$ 64,426
Variable costs						
Labor	\$ 33,283 ⁵	\$ 47,500 ⁶	\$ 33,283 ⁵	\$ 64,804 ⁸	\$114,450 ⁹	\$ 64,804 ⁸
Power	12,852	13,100	12,852	22,580	25,100	22,580
Supplies	42,500	42,500	42,500	85,680	85,680	85,680
Other	<u>5,482</u>	<u>7,100</u>	<u>5,482</u>	<u>14,690</u>	<u>19,770</u>	<u>14,690</u>
Total variable costs	\$ 94,117	\$110,200	\$ 94,117	\$187,754	\$245,000	\$187,754
Sales costs	<u>51,800</u>	<u>51,800</u>	<u>51,800</u>	<u>53,660</u>	<u>53,660</u>	<u>53,660</u>
Total costs	\$217,853	\$221,644	\$213,811	\$309,688	\$377,566	\$306,440

¹Turnkey-plant estimate supplied by equipment contractor-supplier.

²Labor-intensive plant, based on duplication of other Porter's Creek Clay producers; but with higher-temperature calcining equipment.

³Preliminary (pre-pilot testing) estimates

⁴Does not include research and development costs or engineering expenses for proving infrared.

⁵Nine employees

⁶Thirteen employees

⁷A 5 percent increase was added to labor cost for 20,000 TPY plant in Table 8-7 and 2 percent to the cost of supplies to adjust for increased cost five years hence. Miscellaneous costs were also increased slightly to reflect the older plant.

⁸Thirteen employees

⁹Twenty-three employees

Section 9

PROFITABILITY ANALYSIS

Table 9-1 contains a revenue forecast for the first, second, and fifth years.

Table 9-1

REVENUE FORECAST

Year	Sales (Tons)	Average Price Per Ton	Total Revenue
1st Year	10,000	\$ 19.70	\$ 197,000
2nd Year	14,700	19.71	288,000
5th Year	19,400	19.59	387,000

In Table 9-2, the revenue figures for the first and fifth years are combined with cost figures developed in Section 8 in order to compare profitability of the three types of plants.

The sales volume anticipated for the first year is not sufficient to return a profit for any one of the three alternative plants. Even after five years, when maximum sales will have been achieved, the labor-intensive plant shows only a small profit. However, both the capital-intensive and the infrared plants should operate at attractive profits during the fifth year. Because the infrared equipment has not been developed for use in fuller's earth processing, technical feasibility of the infrared plant is questionable. It is concluded however, that the capital-intensive plant is technically and economically feasible.

Table 9-2

COMPARISON OF PROFITABILITY

BY TYPE OF PLANT

Type of Facility	Total Revenue	Total Costs	Net Income
<u>1st Year</u>			
Capital-Intensive Plant	\$197,000	\$217,853	\$(20,853)
Labor-Intensive Plant	197,000	221,644	(24,644)
Capital-Intensive Plant Utilizing Infrared Oven	197,000	213,811	(16,811)
<u>5th Year</u>			
Capital-Intensive Plant	\$387,000	\$309,688	\$ 77,312
Labor-Intensive Plant	387,000	377,566	9,434
Capital-Intensive Plant Utilizing Infrared Oven	387,000	306,440	80,560

In order to determine the point at which the capital-intensive plant would achieve profitability, second year costs for this plant were developed as follows:

Production costs	
Fixed	\$ 68,419
Variable	136,465
Sales costs	<u>51,800</u>
Total costs	\$256,684

Because revenue during the second year is estimated at \$288,000, a profit of \$31,316 is indicated. This is equivalent to 7.8 percent of original capital investment.

DEBT RETIREMENT

Although the capital-intensive plant is considered feasible, it will be necessary to seek a moratorium on principal repayment of the ARA loan. If it is assumed that \$262,360 (65 percent of capital requirement) is borrowed from ARA for a term of 15 years, payments during the first year would amount to \$23,298, of which \$10,260 would be interest and \$13,038 principal. After deductions of interest payments to ARA and other lenders, a loss of \$20,853 results for the first

year. A cash flow of only \$3,937 (depreciation of \$24,790 minus the loss) would be generated during the year. Since principal payments of \$3,563 would be made to other lenders representing (30 percent of capital requirement), it would not be possible to make any payments toward principal from internally generated funds on the ARA loan during the first year.

During the second year, cash flow would amount to approximately \$51,800 (after-tax profits of about \$27,000 plus depreciation). Thus, the firm would be able to begin principal payments on the ARA loan during the second year of operations.

Section 10

RECOMMENDATIONS

PRODUCTION RECOMMENDATIONS

The foregoing profitability analysis indicates that a capital-intensive plant with an initial capacity of 60 tons per day with provisions for expansion to 75 tons per day is economically justified.

To insure low operating costs and guaranteed production, it is recommended that a reputable equipment manufacturer with an experienced engineering-design staff be asked to design and construct an automated plant, and supervise start-up. The profitability analysis is based on conventional and automated equipment and not on new or unproven innovations. If pilot tests indicate that infrared equipment is more suitable than rotary equipment, serious consideration might be given to this method of production.

The Brummitte lease is recommended for the plant site location. Of the two leases under consideration in Marshall County, the Brummitte Farm has the better plant site due to the nearness of the railroad and higher quality clay. A railroad siding is necessary to compete with other fuller's earth producers. The low specific value of absorbent products means they must be sold in large amounts to large resellers, making total reliance on trucking too costly. The smaller distributor and other small buyers who buy on a less-than-one-carload basis will have to be sold by a warehousing broker or distributor rather than in truck-load lots.

PRODUCT RECOMMENDATIONS

The plant initially should manufacture mainly floor absorbent and, on a limited basis, soil conditioner. The market and production costs indicate the greatest and quickest success with these two products.

Future expansion may include additional soil conditioner and a special line of cat litter, perhaps in the 4th or 5th year, depending on marketing conditions at that time. Radioactive filters and industrial-waste absorbents could be subjects for research when the company can afford product development expenses.

MARKETING RECOMMENDATIONS

Company Sales

For promotion work, the new plant will require the services of two salesmen and half the time of the general manager. The sales force should start calling on potential customers shortly after plant construction begins. Company salesmen should establish a broker and distributor network which will be required to achieve sales goals. Initially, brokers will be more desirable than distributors because they provide more services. Several effective manufacturer's representatives also would be desirable. At first, direct sales to consumers are not advised because efforts with resellers will result in more volume movement.

Brokers

Brokers generally sell only to resellers. They are able to promote, warehouse, and sell to many small accounts that the company salesmen cannot afford to contact. Brokers demand and get low prices because they perform a number of promotional services.

Distributors

Distributors are generally of two types: carload buyers and less-than-carload buyers. The former can be contacted on a direct basis at times (depends on timing of purchases) whereas the latter should be handled by a broker, by a commercial warehouse agent, or by a large distributor.

The potential realized in selling absorbent clay products will depend on the number of cooperating distributors and the product quantity they can sell. It probably will be necessary to have at least one effective distributor in each city of more than 250,000 population to sell the plant's output.

Sales Agencies

The Marshall County plant can hire an independent sales agency to initially set up the sales and promotion organization. The sales agencies will contact prospective customers to determine their particular needs and requirements and then write orders for those who are interested. This service costs approximately \$45.00 per day plus nine cents per mile for transportation, for one salesman. Ten regional marketing cities the size of Cleveland could be

serviced for approximately \$20,000 a year. The advantages are many, especially since the first consideration of the principals in the new plant will be solving production problems. Once the plant is operating smoothly, sales can then be managed by a sales force directly controlled by the new plant. Continuing to work the plan established by professional salesmen will make this job easier and much more likely to succeed.

PROMOTION RECOMMENDATIONS

Regardless of how the initial selling phase is handled, the first contacts with potential customers should be to obtain information useful in the product development phase. The needs of users should be studied and new uses might even be found. Ideas that might come from the initial contacts may result in a 30- or 60-pound bag rather than the 50-pound bag, common in the trade. A dispenser or dispensing-type container might also be advised. To combat the bulk density problems, a 60- or 66-pound bag might be introduced at the same price as the competitors' 50-pound bag. Conceivably, such a price cut might accomplish more sales without depressing prices of competitors' 50-pound bags.

Many ideas will have to be tried to find the most profitable approach. If effective promotions are planned and conducted according to market findings of Section 7 and new findings of the sales force, the plant can sell the 10,000 tons for the first year and 20,000 tons by the fifth year. If little or no promotion or enthusiasm is generated, sales will suffer.

SECTION 11

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APPENDIX A :
DRILLING LOGS

Appendix A

DRILLING LOGS

Raymond Powell Farm

Marshall County, Kentucky

Elva Quadrangle

HOLE P-13

Elevation 493.7 feet Total Depth 75.3 feet

Drilling Record:	8-12 feet	4-in. auger
	12-43.2 feet	Fishtail bit
	43.2-45.4 feet	NX spoon
	45.4-75.3 feet	NX core

Post-Eocene continental deposits:

0-1.5	Topsoil, light tan and light red mottled; very fine silt; few roots.
1.5-6	Clay, reddish-brown, micaceous; very fine silt, slightly plastic.
6-8	Clay, as above; some very fine light-tan sand in lower one-half foot; few limonitic chert fragments one-half to one inch in diameter, angular, some moderately round.
8-24	Clay and gravel: clay, as above; gravel, quartz and limonitic chert, small to large; gravel forms up to 40% of total sample in places.
24-27	Silt, sandy, clayey, light reddish-brown, very fine; no gravel.
27-31	Clay, light reddish-brown; silty; no gravel.

Claiborne (?) Formation:

31-41	Sand, tan, fine to coarse; some silt.
41-43.2	No sample.

Porters Creek Clay:

43.2-48.2	Clay, dark black-gray, micaceous, laminated, indurated; number of silty very fine micaceous laminae and blebs, light gray.
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HOLE P-13 (cont'd)

Powell Farm

48.2-55.3 Clay, as above; few to no sandy silt lenses from 49.5 feet to 55.3 feet.
55.3-65.3 Clay, as above; a few silty sand laminae and blebs.
65.3-75.3 Clay, as above; some massive, few very fine sandy silt laminae and blebs, micaceous; few vertical macro joints with b axis of clastic mica flakes normal to the walls.

TOTAL DEPTH: 75.3 feet

HOLE P-16 (1)

Elevation 448 feet Total Depth 32 feet

Drilling Record:	0-3 feet	auger
	3-14.1 feet	NX spoon
	14.1-32 feet	NX core
	0-14 feet	3-in. casing

0-3 Soil; clay, reddish-brown; silty.
3-6 Clay, grayish-brown; laminae and blebs of pale gray material, stiff when slightly moist.
6-7 No sample.
7-9 Clay, reddish-brown, conglomeratic with gravel and sand, hard in dry state.

Porters Creek Clay:

9-14.1 Clay, pale gray, plastic, moist; streaks of reddish-brown limonitic clay.
14.1-23 Clay, medium gray, some laminated, some massive, few streaks of limonitic material.
23-32 Clay, gray to dark gray, laminated, massive in places; some of the laminae appear to be dipping about 8° between 28 to 32 feet.

TOTAL DEPTH: 32 feet

HOLE P-17 (1)

Elevation 462.9 feet Total Depth 40 feet

Drilling Record: 0-30 feet	Fishtail bit
30-40 feet	NX core
0-30 feet	3-in. casing

0-30 Clay, light red-brown to yellow; some limonitic sand and gravel.

Porters Creek Clay:

30-35.7 Clay with sandstone dike splitting half the core; sandstone, fine to coarse, very limonitic, mineralized more at contact with clay, mica; clay, dark gray where not mineralized with limonite, (scaled graphical interpretation suggests the dike is 6 in. thick).

45.7-40 Clay, black-gray, laminated, few thin silt laminae, very fine mica fragments disseminated throughout.

TOTAL DEPTH: 40 feet

HOLE P-21

Elevation 436.7 feet Total Depth 21 feet

Drilling Record: 0-23 feet auger

0-1 Clay soil, umber brown, silty, humic.

1-2 Clay soil, reddish-brown, silty, slightly plastic.

2-7 Clay soil, brown, becoming sandy with depth.

7-8 Clay, reddish-brown; very fine sand and some small gravel; very moist.

8-13 Clay, as above; fine to coarse sand forms 50% or more of sample 11-13 feet.

13-21 Clay, umber-brown; sand, fine to coarse; sand and small gravel forms 60% of sample 15-18 feet.

TOTAL DEPTH: 21 feet

HOLE P-22

Elevation 422.3 feet Total Depth 20 feet

Drilling Record: 0-13 feet	auger
13-20 feet	NX core
0-13 feet	3-in. casing

Porters Creek Clay:

0-2	Clay soil, yellow tan, traces of laminated structure.
2-3	Clay soil, as above, but faintly brown, fragment of gray, sample dry.
3-5	Clay, pale gray to some yellow.
5-7	Clay, brown, some gray blebs, very moist and plastic; no longer has true Porters Creek character.
7-8	Clay, as above; traces of small gravel.
8-11	Clay, as above.
11-13	Clay, brown gray.
13-14.5	Clay, medium gray to dark gray, medium hard, fine silt laminae, some are limonite stained.
14.5-20	Clay, dark gray, occasional laminae of fine mica and quartz sand silt.

TOTAL DEPTH: 20 feet

HOLE P-23

Elevation 423 feet Total Depth 26 feet

Drilling Record: 0-5 feet	auger
5-11.5 feet	NX spoon
11.5-26 feet	NX core
0-11.5 feet	3-in. casing

0-1	Clay, soil, pale gray, some silt, sample dry.
1-3	Clay, red-brown, laminated, some fine sand.

Porters Creek Clay:

3-4	Clay, pale light gray mixed with red clay (Red clay is probably uphole contamination).
4-5	Clay, reddish brown, blebs of gray clay as above; sample mixed with uphole material.
5-6	Clay, brown to yellow brown and pale gray, laminated.
6-11.5	Clay, light gray, some dark gray and yellow brown.
11.5-13	Clay, pale gray to whitish-gray, medium hard, some yellow where limonitic.
13-16.3	Clay, medium gray to dark gray.
16.3-22.6	Clay, dark gray, few sandy silt laminae.
22.6-26	Clay, dark gray, as above; small irregular sandstone mass at 25 feet.

TOTAL DEPTH: 26 feet

HOLE P-24

Elevation 413 feet Total Depth 15 feet

Drilling Record: 0-15 feet auger

0-1	Clay soil, brown, silty, wet.
1-2	Clay, as above; slightly grayish, some small gravel, silty.
2-4	Clay, brown, very sandy, silty.
4-6	No Sample.
6-7	Clay, brown, sand, slightly laminated.

Porters Creek Clay:

7-8	Clay, brown mottled with dark gray, some fine sand and silt on the brown clay.
8-9	Clay, as above, but more of the darker gray, micaceous, wet, plastic.
9-11	Clay, medium dark gray, wet, plastic, some brown clay blebs.
11-12	Clay, dark black gray, moist, plastic, some fine mica.
12-15	Clay, dark black gray, stiff.

TOTAL DEPTH: 15 feet

HOLE P-40

Elevation 431 feet Total Depth 20 feet

Drilling Record:	0-5 feet	auger
	5-10 feet	NX spoon
	10-20 feet	NX core
	0-10 feet	3-in. casing

Recent (soil and possibly some weathered Porters Creek Clay).

0-2.5	Clay soil, reddish-brown, traces of pale gray, faintly laminated.
2.5-3.5	Clay, dark reddish-brown, silty, moist, slightly plastic.
3.5-5	Clay, brown, silty, very little fine sand, moist, slightly plastic, traces of gray clay.

Porters Creek Clay:

5-12.6	Clay, pale to medium gray, darker gray with depth, moist, plastic, hard in places; some limonitic staining along joints and fractures; few micaceous silt and fine sand laminae.
12.6-13.6	Sandstone, fine quartz, very micaceous, some limonitic mineralization and staining.
13.6-18	Clay, medium gray to slightly dark gray, hard; no silt and only traces of mica; few red and yellow limonitic laminae.
18-18.3	Sandstone, fine quartz, very micaceous, limonitic mineralization.
18.3-18.7	Clay, medium gray to gray.
18.7-19.4	Sandstone, fine quartz, micaceous; clay fragments up to 4 mm form 20% of dike.
19.4-20	Mica dike, clayey, clay black; few stringers of pale gray micaceous sandstone with some limonitic mineralization.

TOTAL DEPTH: 20 feet

HOLE P-41

Elevation 438 feet Total Depth 26 feet

Drilling Record: 0-26 feet auger

- 0-1 Clay soil, yellow reddish brown, few streaks
 of pale gray; gray clay is plastic; some
 fine silt; sample is moist.
- 1-2 Clay soil, as above, nearly dry.
- 2-3 Clay soil, yellow brown; fine silt.
- 3-4 Clay, as above; darker and moist.
- 4-5 Clay, brown, some moist and plastic; fine silt.
- 5-6 Clay, umber brown, moist, plastic; fine silt.

Porters Creek Clay:

- 6-7 Clay, pale gray, some yellow brown, moist
 plastic.
- 7-8 Clay, mostly brown with hues of gray.
- 8-10 Clay, as above; specs of white gray clay;
 sandy; some ferruginous material.
- 10-14 Clay, red with some gray brown and gray,
 laminated structures, increase in gray brown
 and gray with depth; some uphole contamination
 of material similar to samples from 8 to 10 feet.
- 14-17 Clay, gray to gray brown, moist, plastic.
- 17-21 Clay, medium gray, moist, plastic.
- 21-26 Clay, gray to dark gray, moist, plastic; some
 fine silt and mica.

TOTAL DEPTH: 26 feet.

HOLE P-42

Elevation 451 feet Total Depth 39 feet

Drilling Record: 0-39 feet auger

- 0-1 Top clay soil, humic, dark gray brown, fine
 silt, moist.

- 1-2 Clay soil, red orange, fine silt, some blebs of brown clay, slightly moist.
- 2-3 Clay soil as above; some pale gray blebs, gray is faintly laminated.
- 3-4 Clay soil, dark reddish-brown, silty, slightly laminated, dry.
- 4-5 Clay soil, fine silt, pale dusty yellow brown when dry, pale brown when wet; sample is dry.
- 5-6 Clay, pale dusty yellow gray when dry, brown when wet; sample is dry.

Porters Creek Clay:

- 6-7 Clay, as above; some yellow brown and light pale gray clay, laminated, slightly moist.
- 7-9 Clay, as above, but more of the clay is pale gray; slightly moist in the centers.
- 9-10 Clay, pale gray, some medium brown, some yellow limonitic staining, moist, slightly plastic.
- 10-11 Clay, medium brown gray, slightly plastic.
- 11-20 Clay, gray, moist, plastic, traces of yellow brown clay.
- 20-25 Clay, dark gray, moist, plastic, partly contaminated with yellow brown clay from above.
- 25-39 Clay, dark black gray, relatively unweathered in lower half.

TOTAL DEPTH: 39 feet

HOLE P-43

Elevation 435 feet Total Depth 31 feet

Drilling Record: 0-31 feet auger

- 0-1 Clay soil, yellow brown, loamy, humic, moist.
- 1-10 Clay, brown to red brown, some silt and fine sand throughout, moist, plastic.

Porters Creek Clay:

10-15 Clay, brown gray, micaceous, laminated,
moist, stiff.
15-17 Clay, dark gray, some brown gray, mica,
little fine silt.
17-23 Clay, dark gray, moist, stiff, some fine mica.
23-31 Clay, dark black gray, micaceous, moist, very
stiff, little very fine silt.

TOTAL DEPTH: 31 feet.

HOLE P-44

Elevation 435 feet Total Depth 25 feet

Drilling Record: 0-25 feet auger

0-1 Top soil, dark brown clay, some silt, humic
moist to wet.
1-2 Clay, yellow reddish brown, silty, moist,
plastic.

Porters Creek Clay:

2-5 Clay, yellowish brown, faint hues of pale
gray, silty, very fine, very moist, plastic.
5-8 Clay, red mottled with red brown, some hues
of pale gray, laminated, moist, plastic.
8-10 Clay, yellow reddish brown, some gray,
slightly laminated, moist, plastic.
10-11 Clay, gray brown to brown gray, moist,
plastic, traces of red brown clay from above.
11-15 Clay, dull medium gray, wet.
15-25 Clay, gray to dark gray, moist, stiff,
probably relatively unweathered.

TOTAL DEPTH: 25 feet.

HOLE P-45

Elevation 454 feet Total Depth 20 feet

Drilling Record: 0-20 feet auger

0-1 Topsoil, brown, silty, clay, humic, moist.
 1-6 Soil, silt, clay, yellowish brown, some
 brown laminated clay, dry.
 6-10 Clay, yellowish brown, wet 6-9, dry 9-10.
 10-12 Clay, yellowish brown, silt; 60% chert gravel.

Porters Creek Clay:

12-16 Clay, red, laminated, some fine silt; some
 mixing with uphole material.
 16-17 Clay, yellowish brown, moist, plastic.
 17-19 Clay, gray brown to brown gray, moist, plastic.
 19-20 Clay, gray, moist, plastic.

TOTAL DEPTH: 20 feet

HOLE P-46

Elevation 472 feet Total Depth 30 feet

Drilling Record: 0-2 feet auger
 2-12 feet NX spoon
 12-30 feet NX core
 0-12 feet 3-in. casing

0-1 Clay soil, reddish yellow brown, very fine
 silt, plastic when moist.
 1-3.5 Clay, reddish brown, few streaks of pale gray
 clay, laminated; some ferruginous material in
 the reddish brown clay and some limonitic
 chert gravel.

Porters Creek Clay:

3.5-5 Clay, medium gray, some limonitic stained clay,
 plastic when moist.

5-6 Clay, reddish yellow brown, sandy, silty, conglomeritic in places, moist.
6-7 Sandstone, yellow tan, very fine, friable; apparently a weathered sand dike.
7-8 Clay, yellowish brown, some pale gray.
8-10 Clay and sandstone: clay, yellow brown, some pale gray, laminated, plastic when moist; sandstone, limonitic, clayey, friable, possibly a dike emplacement.
10-12 Clay, medium gray, laminated, some limonitic streaks along joints and silt laminae, micaceous.
12-14 Clay, as above; slightly darker gray, some red and brown clay, silty, very micaceous, number of silt laminae.
14-30 Clay, as above; gray and becoming almost dark black gray at 23 feet.

TOTAL DEPTH: 30 feet

HOLE P-47

Elevation 419 feet Total Depth 74 feet

Drilling Record: 0-4 feet auger
 4-10 feet NX spoon
 10-74 feet NX core
 0-10 feet 3-in. casing

0-1 Clay soil and gravel: soil, yellow brown, silty, sandy; gravel, limonitic chert, small to large moderately rounded.

Porters Creek Clay:

1-4 Clay, light gray, some yellow and red brown streaks; upper 1 in. plastic, lower 3 in. stiff; fine mica throughout.
4-10 Clay, medium gray, numerous limonitic filled macro joints, number of thin silt laminae and silt blebs, limonitic.

10-13	Clay, medium gray to gray, laminated, dipping 30° or more, many slickensides; yellow brown clay and limonitic chert gravel 11.5 to 12 feet.
13-19.6	Clay, dark gray, faintly green, fine mica and silt, laminated, dipping 30°.
19.6-19.9	Sandstone, dark black green, glauconitic, very micaceous, foliation of mica approximately 45° to the horizontal; slickensides with clay above and below.
19.9-23	Clay, dark black gray, broken, some soft, fragments of sandstone from above.
23-27	Sandstone, dark black green, glauconitic, very micaceous, foliation of mica 45° to the horizontal contact with clay above 70° to the horizontal.
27-28	Clay, dark black gray, hard, micaceous, fragments of sandstone from above.
28-29	Sandstone, dark black green, glauconitic, very micaceous, foliation of mica 10° to the horizontal.
29-30	Clay, dark black gray, weathered, crumbly.
30-36	Clay, black gray, faintly green, hard, micaceous, some silt, few slickensides.
36-46	Clay, black gray, hard, some laminated, horizontal, some massive, micaceous, silty, occasional blebs of light gray fine sand.
46-50	Sandstone, dark black green, glauconitic, very micaceous, 2 in. of clay in base (sandstone may all be caved material).
50-55	Clay, black gray to black, increase in mica content, silty in places.
55-65	Clay, as above; silty, micaceous, some silty micaceous laminae, mostly massive.
65-74	Clay, as above; hard, massive, less mica and silt, few vertical joints with "washboard" surfaces.
TOTAL DEPTH:	74 feet

J. D. Brummitte Farm
Marshall County, Kentucky
Elva Quandrangle

HOLE B-14

Elevation 437.5 feet Total Depth 70 feet

Drilling Record:	0-6 feet	auger
	6-8 feet	NX spoon
	8-11.5 feet	BX spoon
	11.5-70 feet	NX core
	0-6 feet	3 in. casing

0-4 Soil, brown, clay and gravel, dry, roots.

Porters Creek Clay:

4-8	Clay, medium gray, plastic when very moist, stiff when slightly moist.
8-10	Clay, as above; laminae of white silt sand.
10-17.5	Clay, medium gray, some highly weathered zones; 20% gravel from 12.5 feet to 13.5 feet (possibly the filling of a root cavity; source no more than speculative).
17.5-19.5	Clay, gray to dark gray, number of limonitic streaks, laminated, laminae dip approximately 10°, white to pale gray silt laminae form 5% of sample.
19.5-21.5	Clay, gray, few to no silt laminae and limonitic streaks.
21.5-29.5	Clay, gray to dark gray, some mica, occasional slickensides, weathered soft 23.5 to 24.5 feet; few vertical joints mineralized with limonitic material 27.5 to 29.5 feet.
29.5-36.5	Clay, dark gray to black gray, micaceous silt laminae.
36.5-44	Clay, black gray, indurated, number of micaceous silt laminae in places, slickensides in lower 2 feet, laminae dipping approximately 10°.
44-46	Clay, dark gray, indurated, micaceous silt laminae in lower 1 foot, laminae dipping 30°-40°.
46-48	Clay, dark black gray, indurated, micaceous, practically no silt laminae, laminae dipping 5°.

48-56 Clay, as above, indurated laminae relatively horizontal, micaceous but no silt laminae seen in wet core, some vertical or nearly vertical joints.

56-66 Clay, as above, laminae horizontal, micaceous silty sand blebs, very micaceous and silty in lower 3 feet.

66-70 Clay, as above, some massive, vertical joints with macro "washboard" surfaces.

TOTAL DEPTH: 70 feet

HOLE B-15

Elevation 407 feet Total Depth 35 feet

Drilling Record: 0-7 feet NX spoon
 7-35 feet NX core

Porters Creek Clay:

0-0.5 Top soil; clay, red brown, moist, stiff; roots.

0.5-9 Clay, pale gray with yellow brown streaks, becomes darker gray with depth, micaceous, silty.

9-13 Clay, gray to dark gray, some black gray, hard with intermittent zones weathered soft, occasional limonitic stained streaks.

13-19 Clay, gray, weathered soft.

19-21 Clay, dark gray, hard.

21-23 Clay, yellowish gray, silty, highly weathered, some dark black gray and light gray clay.

23-25 Clay, dark black gray, laminae of pale yellow and white gray silt.

25-27 Clay, dark black gray, unweathered, hard, same as above, slickensides 26.5 to 27.5 with multiple directions of striae.

27-29 Clay, gray, brown, highly weathered, blebs of yellow stained limonitic clay.

29-31 Clay, dark black gray, unweathered; hard occasionally thin lenses of pale dust gray silt; numerous slickensides 29-31 with random orientation.

31-35 Clay, medium gray to gray, soft to medium hard, some yellow brown clay streaks.

TOTAL DEPTH: 35 feet

HOLE B-16

Elevation 375 feet Total Depth 15 feet

Drilling Record: 0-7 feet NX spoon
 7-15 feet NX core

0-3 Clay soil, brown, gray brown and yellow brown, silty; some gravel.

3-5 Clay, red, brown to yellow brown, laminated; some red chert gravel.

Porters Creek Clay (?)

5-7 Clay, medium gray, yellow limonitic streaks, medium weathered; some gravel (contamination down root cavity?).

7-9 Clay, medium gray, laminated, moist, numerous limonitic clay streaks.

9-11 Clay, as above; clay-gravel conglomerate in lower $\frac{1}{2}$ foot, possibly contamination.

11-14 Clay-gravel conglomerate, red brown, very sandy.

14-15 Clay, pale gray, 10% gravel, 25% gravel in lower 3 inches.

TOTAL DEPTH: 15 feet.

HOLE B-18

Elevation 372 feet Total Depth 21 feet

Drilling Record:	0-2 feet	auger
	2-11 feet	NX core
	11-21 feet	Fishtail bit
	0-8 feet	3-in. casing

0-4 Clay soil, red brown; lots of chert gravel, silty, sandy.

4-7 Clay, medium gray and red brown, inter-laminated with silt laminae; 30% ferruginous chert gravel. Gravel, sand and clay, red brown.

Porters Creek Clay:

20-21 Clay (no samples) water flushed gray.

TOTAL DEPTH: 21 feet

HOLE B-19

Elevation 392 feet Total Depth 35 feet

Drilling Record:	0-3 feet	auger
	3-11 feet	NX spoon
	11-28.5 feet	NX core
	28.5-35 feet	BX spoon

Porters Creek Clay:

0-1 Clay, medium gray to red brown, micaceous, few silt laminae; 5% of sample is chert gravel.

1-5 Clay, medium gray, streaks of brown, laminated, silt laminae, laminae dipping 15°.

5-7 Clay and conglomeritic clay: clay, 50%, medium gray, some yellow brown, laminated, medium hard; conglomeritic clay, 50%, limonitic chert gravel.

7-11 Clay, gray, semi-hard in places, micaceous, silty, thin lenses of gravel and sand 9 to 10 feet.

11-20	Clay, gray to dark gray, laminated, occasional micaceous silt laminae.
20-22	Clay, gray to dark gray, highly weathered, few limonitic streaks, laminae dipping 25-30°.
22-28.5	Clay, gray to dark gray, weathered, micaceous silt layer 28 to 28.3.
28.5-30.5	Clay, as above, weathered, laminae dipping 25-30°.
30.5-35	Clay, as above; micaceous sand lenses and blebs in lower 5 inches.

HOLE B-20

Elevation 403 feet Total Depth 27 feet

Drilling Record: 0-27 feet auger

Porters Creek Clay:

0-2	Clay, pale light gray, micaceous.
2-6	Clay, pale to medium gray, micaceous.
6-13	Clay, medium gray to dark gray with depth, moist, slightly plastic.
13-27	Clay, gray to dark gray, becomes relatively hard with depth in unweathered portion.

TOTAL DEPTH: 27 feet

HOLE B-30

Elevation 403 feet Total Depth 37 feet

Drilling Record: 0-3 feet auger
 3-37 feet BX spoon

0-3	Clay soil, red brown, brown, some gray, silty; occasional small gravel.
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HOLE B-30 (cont'd)

Brummitte Farm

3-7 Clay, various hues of brown, some gray and white; gravel.
7-37 Clay and gravel, very sandy, red and brown; cavity with water 25 to 27.

TOTAL DEPTH: 37 feet

HOLE B-31

Elevation 439 feet Total Depth 60 feet

Drilling Record:	0-4 feet	auger
	4-14 feet	BX spoon
	14-60 feet	NX core
	0-10 feet	3 in. casing

0-1 Soil, clay and gravel, silt, light brown tan.

Porters Creek Clay:

1-4 Clay, pale light gray and brown, laminated, micaceous.
4-14 Clay, medium gray to light gray, micaceous, silty, hard, laminae dipping 5°, some limonitic streaks.
14-17 Clay, gray, few silt laminae and blebs of light gray sand, some are limonitic.
17-20 Clay, dark gray, silt laminae and blebs 19 to 20.
20-30 Clay, dark black gray, micaceous, silt, some limonitic mineralization along macro joints; increase in silt content in lower 5 feet.
30-40 Clay, black gray, laminated, some massive, laminae dipping 5° or less.
40-50 Clay, as above.
50-60 Clay, as above; hard; lower 3.6 feet lost in hole.

TOTAL DEPTH: 60 feet

HOLE B-2

Elevation 379.6 feet Total Depth 20 feet

Drilling Record: 0-20 feet auger

0-2	Chert gravel and dark gray soil, moist.
2-3	Clay, red, laminated, some silt.
3-5	Clay, as above, small ferruginous gravel.
5-7	Clay, red with some brown; small gravel.
7-20	Clay and gravel, orange red, dry.

TOTAL DEPTH: 20 feet

HOLE B-6

Elevation 377 feet Total Depth 20 feet

Drilling Record: 0-20 feet auger

0-1	Top soil, brown and yellow brown; clay, silty; some gravel.
1-3	Clay soil, red brown, silty, moist, slightly plastic.
3-4	Clay, dark reddish brown, silty, moist, slightly plastic; no gravel or sand.
4-5	Clay, faintly gray brown, moist.
5-9	Clay, dark reddish brown and gray brown, moist.
9-14	Clay, dark reddish brown to brown, silty, very moist, plastic; some small gravel and trace of sand 12 to 13.
14-20	Clay, red brown to brown, lots of silt and fine sand, stiff.

TOTAL DEPTH: 20 feet

HOLE B-7

Elevation 381 feet Total Depth 20 feet

Drilling Record: 0-20 feet auger

0-2	Soil, brown, clayey, humic; some limonitic chert gravel.
-----	--

Porters Creek Clay:

2-6 Clay, pale gray to brown gray, moist, plastic, occasional silt; traces of small limonitic gravel.

6-11 Clay, yellow brown, very micaceous, silty, moist, plastic, blebs of gray, some mottling of brown and gray.

11-13 Clay, orange brown, micaceous, very moist, plastic, becomes medium gray at 14 feet with some mottling of brown.

13-16 Clay, gray brown to brown gray, very moist, plastic, becomes medium gray at 14 feet with some mottling of brown.

16-20 Clay, medium gray to gray, laminated, streaks of limonitic clay, moist plastic.

TOTAL DEPTH: 20 feet

HOLE B-9

Elevation 371 feet Total Depth 20 feet

Drilling Record: 0-20 feet auger

0-20 Conglomeratic clay, dry, hard.

TOTAL DEPTH: 20 feet

HOLE B-11

Elevation 411 feet Total Depth 36 feet

Drilling Record: 0-36 feet auger

0-5 Chert gravel, limonitic, small to 1 in. moderately round to sub-angular, some clay soil matrix.

5-6.5 Chert gravel, as above but smaller, $\frac{1}{4}$ inch or less.

Porters Creek Clay:

6.5-11 Clay, light medium gray, some yellow brown,
moist, plastic, becomes darker with depth.
11-16 Clay, medium gray, micaceous, no contamination.
16-21 Clay, dark medium gray, micaceous.
21-25 Clay, gray.
25-32 Clay, gray, some slightly yellow brown.
32-34 Clay, gray.
34-36 Clay, gray, some yellow brown material from
uphole; contamination 5% of total sample.

TOTAL DEPTH: 36 feet.

HOLE B-13

Elevation 404 feet Total Depth 45 feet

Drilling Record:	0-3 feet	auger
	3-40 feet	NX spoon
	40-45 feet	Fishtail bit
	0-36 feet	3 in. casing

0-1 Top soil, reddish brown, clayey, silty; some
gravel.
1-5 Clay and silt, brown red, traces of laminated
structure; some ferruginous gravel in lower
two feet.
5-45 Conglomeratic clay, red, limonitic chert gravel,
fine to one inch.

TOTAL DEPTH 45 feet.

APPENDIX B:
CLAY SAMPLING AND TESTING PROCEDURES

APPENDIX B

CLAY SAMPLING AND TESTING PROCEDURES

SAMPLE PREPARATION

Approximately 1000 grams of each core sample were dried at 95°C and ground in a Fitzmill containing a screen with 0.40-inch diameter holes. A sieve analysis was run on each lot, divided as follows:

<u>Hole</u>	<u>Depth (feet)</u>	<u>Hole</u>	<u>Depth (feet)</u>
P-16	9-19 19-29 29-32	B-14	4-14 14-24 24-34 23-44
P-23	3-13 13-23 23-26		44-54 54-64 64-70
P-40	5-15 15-20	B-15	0-11 11-20 20-31 31-35
P-41	6-16 16-26		
P-42	6-16 16-26 26-30	B-19	0-10 10-20 20-30.5
P-46	3.5-13 13-23	B-20	0-10 10-20 20-27

After grinding, samples to be tested were heated in an electric furnace to 371°C (700°F) and 649°C (1200°F) as indicated in Tables 5-4 and 5-6.

X-RAY ANALYSIS

Three grams of each clay sample were thoroughly mixed, ground in a mortar and pestle, and placed in a four-ounce jar full of de-mineralized water. A small amount of sodium hexametaphosphate was added to prevent flocculation. After thoroughly shaking the mixture to better fractionate the clay, it was allowed to stand for one hour. Two cubic centimeters were pipetted from a point one quarter of an inch below the liquid surface and then deposited on a microscope slide. The purpose of the

settling was to obtain particles of less than two microns in size. After drying, the slide contained oriented particles (the clay minerals are plate-like), ready for X-ray analyses (number 1 traces in Figure 5-1). Unoriented powder samples were prepared by using conventional sample holders containing material ground to minus 100 mesh.

X-ray diffraction patterns were obtained with a General Electric XRD-5 unit. The less-than-two-micron samples, after scanning from 2° to 30° were treated with ethylene glycol vapor in a dessicator-type container. The ethylene glycol molecules replaced water between the montmorillonite layers and expanded the structure from about 14 to 17.7 Angstroms as revealed by the X-ray diffraction patterns (see Figure 5-1, number 2 traces). Samples were also heated to 371°C (700°F), evaporating all of the ethylene glycol and reducing the distance between structural layers to about 10 Angstroms, as shown by the X-ray diffraction patterns in Figure 5-1 (number 3 traces).

Definitions of terms and descriptions of X-ray diffraction characteristics of clay minerals are available in a standard reference.¹

DECOLORIZATION

The degree of decolorization of crude soy bean oil by clay was determined by measuring the percent of light transmission at 460 millimicrons wave length. Ten grams of ground clay were mixed with 40 cc of benzene and a given percentage of crude soy bean oil in a 250-cc Erlenmeyer flask. The stoppered flask was agitated for 30 minutes. The mixture was then filtered through Whatman No. 3 filter paper. The filtrate was placed in a test tube and the percent transmission measured at 460 millimicrons on a Bausch and Lomb "Spectronic 20", calibrated at zero and 100 percent by using pure benzene.²

¹Brown, G. (editor), X-ray Identification and Crystal Structures of the Clay Minerals, Mineralogical Society of Great Britain Monograph , 1961.

²T.A. Klinefelter and H.P. Hamlin, "Syllabus of Clay Testing" U.S. Bureau of Mines Bulletin 565, 1957, p.47.

OIL RETENTION TEST

The objective of the oil retention test was to determine the amount of oil retained when the clay was used to bleach oils. The test also provided an assessment of the clay as an absorbent on floors. In the former case, it was desirable to have a low oil retention value. In the latter case, a high value.

Oil was added slowly to 10 grams of clay in a 250-ml beaker with a spatula. The end point was reached when a putty-like paste was formed and the mixture could be pushed against the side of the beaker, while leaving a very thin oil smear on the glass. The value is expressed as the percent of oil used (oil divided by the clay, times 100, on a weight basis).

RESISTANCE TO BREAKDOWN WITH WATER

If the product does not break down in water, it will be less messy, have a longer useful life, and be more economical to use as a floor absorbent.

Fifteen grams of minus 10 mesh, plus 30 mesh clay were placed in a six ounce jar; 50 ml of de-mineralized water were added and the mixture shaken for one minute. A 2-cc sample was pipetted, transferred to a tared crucible, and dried at 100°C to a constant weight. Percent breakdown equals the weight of the solids in the crucible, multiplied by 500, and divided by the weight of the sample. (Factor of 500 derives from factor of 5 to convert portion withdrawn to total breakdown and factor it 100 to convert it to percentage basis).¹

APPARENT DENSITY

Federal specifications on sweeping compounds P-S-008656 (GSA-FSS) were used to determine the apparent density (product bulk density). The clay was graded according to paragraph 3.4 of the above specifications as follows:

<u>U.S. Standard</u> <u>sieve number</u>	<u>Percent Retailed</u>	
	<u>Minimum</u>	<u>Maximum</u>
30	52	78
40	73	90
60	90	97.5

¹Wyandotte Chemicals, J.G. Ford Division Publication, F-6584.

A 250-ml, weighed, graduated cylinder is filled with the sample to approximately the 240-ml mark. The material is settled by raising the cylinder approximately one inch above the surface of a lead sheet and allowed to fall freely. This is repeated seven more times. The volume of the settled material is read to the nearest ml and weighed to the nearest 0.1. Density in pounds per cubic feet equals the weight of sample in grams times 62.43, divided by the volume in milliliters after settling.

SLAKING TEST

To test the slaking properties, large pieces of clay were placed in a beaker of water. Fuller's earth generally splits into large irregular fragments with no mud, whereas most other clays break up into fine particles.¹ All Porter's Creek Clay samples tested slaked into large, irregular fragments.

ACID TREATMENT

One hundred grams of clay were placed in a 100-cc beaker, and 60 cc of concentrated H_2SO_4 and 540 cc of water were added. The mixture was boiled for one hour on a hot plate. After cooling and allowing the clay to settle, the clear liquid was decanted and 600 cc of de-mineralized water added. This was repeated five times. The residue was then filtered out, washed five times, allowed to drain overnight, and then dried at 100°C for 24 hours. The dried, acid-treated clay was crushed, ground, and graded in the same manner as raw clay.

¹Klinefelter and Hamlin, Op.cit.



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